UNIVERSITY OF ALBERTA

TOWARD A VIEW OF HEALTHY LEARNING ORGANIZATIONS THROUGH COMPLEXITY

by

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fulfillment of the requirements for the degree of Doctor of Philosophy

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Abstract

This thesis, a speculative essay, examines a collection of theoretical concepts and principles, largely drawn from the still-emerging domain of the complexity sciences, which can be used to describe, model and understand learning organizations like schools and other educational settings that might be thought of as healthy learning organizations. Through a set of analogies with healthy and unhealthy physiological organizations, broadly speaking, this work offers a view of healthy learning organizations.

This work begins with an examination of a few key theoretical frames about dynamical systems most appropriately described through the frames of chaos theory, catastrophe theory and critical self-organization, as well as their attending conceptual underpinnings and assumptions.

The notion of *surprise* is then examined for some of its phenomenological aspects with the anticipation that this might lend to some possibilities for thinking about the phenomenon from a complexity science perspective. Some insights into the ways in which people might perceive surprise in the context of organizations when framed by different metaphorical images for organizations are also considered.

Thinking about metastable patterns, I offer a view about robust coherent qualities of organizations that attempts to move away from a metaphorical framing of organizations as if they were either machines or

holistic phenomena. Thus, I invent the notion of "comparative dynamics" to highlight different organizational metastable patterns with tendencies for particular qualities.

The final sections of this work examine my own experiences with a "learning organization." The organization, which is not a formal educational institution, offers up some useful insights and possibilities for thinking about and enacting some different sensibilities for diverse educational settings and configurations. In so doing, I offer and reflect upon some of my own experiences as I think about what a school might look like as a healthy learning organization.

To assist my readers along the way, I have also provided a glossary of terms that are highlighted as boldface text throughout this work. These are terms that my readers might find a bit more technical and are flagged in this way so as not to disrupt the flow of the main text.

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First, and foremost, I have my supervisor Brent Davis to thank for his tremendous amount of support throughout my program of study and the writing of this dissertation. I feel that the many important events that have helped to shape my thinking could not have happened otherwise. I have learned much from Brent's creativity, as well as, breadth and depth of knowledge.

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Preface

SETTING THE STAGE: AN OVERVIEW

> *I think that even though we need to have some outline, I am sure that we make the road by walking.*[1]

This dissertation is a move towards an exploration of an understanding of healthy organizations across different scales of organization. Through the use of analogies and the embodiment of dynamic principles, it is my aim to offer a particular view of patterns that arise from social interactions in organizations, broadly speaking, and of education, specifically, that could be said to be "healthy." Drawing upon current emerging views of paradigmatic complexity and a quality of human physiological phenomena described as "healthiness," the stage is being set for a description of social phenomena that could be described as "healthy organizations." This said, how might one think about healthy organizations in the context of education in its many scales of complexity?

Consciously or otherwise, the layout or rather gradual unfolding of this dissertation could be said to flow as an evolution of my own thinking and interests and is presented here, in a textual direction, marked by five possible orienting frames: foundations, constructions, explorations, reflections, and projections.[2] My readers may find this work at first to be a bit quiet in terms of my own "voice," personality and level of engagement. Even more, one might ask, what does this work have to do with education or say to people in the education field? These points become more and more evident and clear with each chapter and orienting frame (as described below). As such, I beg the indulgence of my readers to "walk along with me."

---

[1] Myles Horton and Paulo Freire, *We Make the Road by Walking: Conversations on Education and Social Change*, ed. Brenda Bell, John Gaventa, and John Marshall Peters (Philadelphia: Temple University Press, 1990), 6.

[2] Interestingly enough, this introduction was written near the end of this work. It is, therefore, only in hind-sight that these orientations have emerged as a description of the layout of the dissertation. Moreover, quite by chance, it was the prefatory remarks on the organization of Mitchel Resnick's book from which I have taken these orientations to describe the layout and flow of this work. The division of his book according to foundations, constructions, explorations, reflections, and

The relationships here, between and across the different chapters as they stand, are much too complex (in a not-so-technical use of that notion) and multidimensional to not present them in some ordered and orderly fashion for others. To be clear, this work has unfolded like many of the truly wonderful and influential conversations, readings and insights that I have had over the past few years. It has emerged in, from and around great moments of playfulness and generativity, and the seeming disorder has been played with to create something else a bit more "efficiently structured." Those many conversational and intellectual strands are ***woven*** here together in this single strand. Fittingly, and etymologically so, that is this *text* and the con*text* for this piece.[3]

As for a brief outline, here are the orienting frames which lay out a path for walking along and through this work:

> *The* ***foundations*** *for this work are framed by a historical view of complexity-related frames.*

---

projections has proven to be a fortuitously useful description of the unfolding of this work. *Cf.*, Mitchel Resnick, ***Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds*** (Cambridge, MA: MIT Press, 1994).

[3] As an etymological flag, the word "text" (as well as "context") suggests a weaving of sorts. A "context," from the Middle English and Latinate root, ***contextus***, implied a weaving together or connecting of words. It is also related to the technical arts (L., ***techne***).

The 20th century has seen a rise in conceptual tools and theoretical perspectives for the purpose of describing, understanding and creating the kinds of conditions for a wide range of phenomena that I would describe as "paradigmatically complex." Historically speaking, a number of different complexity-related theoretical frames, which include but are not limited to catastrophe theory, chaos theory, self-organized criticality, and complex adaptive systems, have emerged to describe a class of phenomena encompassing a wide range of forms, scales of organization and organizational dynamics. Arguably, a broad trend has emerged across the natural sciences for a larger perspective of various dynamic phenomena in the world framed by these complexity-related theories. Moreover, the social sciences also have seen similar discourses emerge, sometimes under the direct influence of or adaptation from the natural sciences.

Chapter 1, therefore, provides some historical background on some of the more well-known complexity-related theoretical frames. A distinction between phenomena that are complex and not complex is examined with subsequent attention given to the technical conceptualization of chaos and chaos theory, catastrophe theory, self-organized criticality and complex adaptive systems. The history of non-linear dynamics, of course, is much more extensive than what can be presented here. The influence that these particular frameworks have, however, in many of today's more prominent discourses and discussions about complex systems make them relevant for review and use in this work.

> *The constructions for this work are framed by an examination of a number of prominent and useful conceptual ideas or principles behind a number of complexity frameworks.*

In Chapter 1, a collection of theoretical frames are introduced that describe a variety of features and aspects of complex phenomena. In addition, there are a number of key conceptual ideas or principles that are common to these theoretical frames. As such, the concepts of non-linearity, emergence, self-organization, diversity, interaction, redundancy and fractal will be examined. Chapter 2, therefore, provides some elaboration on a set of complexity concepts that are key to the theoretical frames introduced in the previous chapter. These concepts are presented and reviewed, and will become a part of the conceptual "toolkit" for examining and exploring the notion of "healthy learning organizations" to be introduced subsequently.

Chapters 1 and 2 are important to this work for a few reasons. As a work concerned with dynamical phenomena of various kinds, it is important to situate it historically, culturally and conceptually. Of these three, the conceptual framing is most important as it will prove useful for readers with varying degrees of understanding of various concepts, dynamical forms and the assumptions that form the basis for an understanding of those forms. Moreover, many of these concepts will be invoked throughout this work and, as such, will be necessary for further elaboration in subsequent chapters and the development of some new ideas.

> *The explorations for this work are framed by an engagement with some new ideas for thinking about "healthy dynamical patterns" and a complexified understanding of the notion of surprise and its implications for thinking about healthy learning organizations.*

Chapters 3 and 4 touch upon two different topics: the enigmatic notion of healthy organizations and the experience of surprise.

A new term, "comparative dynamics," is introduced with the intention of comparing the dynamical patterns of different kinds of phenomena.

Comparative dynamics focuses on the dynamical patterns of organizations. More specifically, comparative dynamics is a systemic comparison of similarities and differences *at the level of the dynamical patterns* within a particular *kind* of organizational phenomenon. Put differently, Chapter 3 will provide an examination of different physiological phenomena and introduces a qualitative distinction between healthy and unhealthy dynamics and dynamical patterns through this notion of comparative dynamics.

The notion of surprise is a phenomena addressed by a number of different disciplines, especially in the context of complexity discourses which have been described as a science of surprise by some. Chapter 4 presents a view of the lived-experience or phenomenology of surprise and offers some possible complexity-inspired models for understanding the lived-experience. In addition, the chapter also will examine some possible implications for thinking about surprise in the context of different conceptualizations of organizations. As such, the lived-experience surprise is considered in light of the notion of comparative dynamics that I introduce in the previous chapter.

Chapters 3 and 4 also will touch upon, to some degree, the nature and role in which metaphors are used and structure the ways in which organizations might be understood. The "invention" of comparative dynamics emerged from a sense that two very different metaphorical constructs (*i.e.*, machines and living entities) seemed to be less than compelling descriptions for social organizations. The introduction of comparative dynamics is made with the effort to bridge these two conceptual metaphors for organizations while attempting to be more attentive to the underlying dynamics of organizations that bring forth these two different metastable patterns. These two metaphors are not altogether inappropriate descriptors for social organizations and are, I propose, seemingly adequate for describing many different kinds of organizations–physiological, biological, sociological and ecological. These chapters open the way for thinking about a different metaphor for organizations: health.

Chapter 3 is essentially the conceptual crux of this work. The term "comparative dynamics" emerged rather serendipitously at a time when I was trying to make sense of organizations that could manifest a wide range of possible patterns. At the same time, I found the use of certain metaphors (*i.e.*, the organizational metaphors of machines and living systems) to describe people's experiences within and the "behavior" of an organization to be a bit troubling although the use of these metaphors seem compelling enough and consistent with certain organizational patterns. This chapter is my attempt to make sense of a wide range of organizational possibilities without reducing those possibilities to some dichotomy of metaphors that always simultaneously illuminate and hide potential aspects of those organizations. As a baseline example–referent analogies–I refer to the dynamics and patterns of the human heart and gait as a means to connect with other scales of organization to be examined throughout the remaining sections of this work.

> *The reflections for this work are framed by some of my own experiences with coordinating and participating in a number of educational events framed explicitly by complexity-related ideas and offers an image of a healthy learning organization.*

Chapter 5 presents some thoughts on my own previous work, in the form of an auto-ethnography, with a non-profit organization and more specifically reflections on the design of and conditions for a healthy learning organization that are manifest across many scales of organization. Following a number of important complexity principles, occasioning learning events and new possibilities for action and insight informed by these principles have been a trademark for thinking about and planning for all of this organization's work. As a model for learning organizations in general, there are some possible implications at work in this organization for thinking about many aspects and dimensions of the education system, including, for instance, schools, classrooms, curriculum studies and policy development, teacher education programs and issues of leadership, and learning in general. Some of these aspects will be considered and examined in the final chapter.

> *The projections for this work are framed by some final thoughts for thinking about some aspects of education in light of the image of healthy learning organizations.*

Chapter 6 is the final chapter and an examination of certain aspects of education in light of the emergent thinking of complex phenomena, healthy dynamics and organizations, and social interactions.

Although not a formal part of this work, the *dénouement* is a final "dwelling place" for my own reflections on the evolution of this piece of writing. The *dénouement* explores some of the difficulties or challenges which this work still faces and the messiness that comes with doing scholarly work.

Last, to help my readers through the messiness of dealing with some potentially new and puzzling vocabulary, I have included a glossary of terms. That is, a significant number of technical terms have been identified and flagged throughout this work. In the main text, they are marked in **bold** the first time they are mentioned as a reminder that some kind of elaboration is provided where there may be a need for some further insight into their possible meaning.

Chapter 1

A HISTORY OF COMPLEXITY THEORETIC FRAMES[4]

Trends in the Evolution of a Scientific Paradigm

> *Isn't the very idea of following a line of development, century by century, inherently linear? My answer is that a nonlinear conception of history has absolutely nothing to do with a style of presentation, as if one could truly capture the nonequilibrium dynamics of human historical processes by jumping back and forth among the centuries. On the contrary, what is needed here is not a textual but a physical operation: much as history has infiltrated physics, we must now allow physics to infiltrate human history.*[5]

Currently, "paradigmatic complexity" is a notion invoked across a wide range of discourses, scholarly discussions and writings, and practical engagements with organizational or systemic structures. A growing number of scientists, scholars and researchers from various disciplines and interdisciplinary domains are embracing this emerging understanding of various phenomena that has extended and sometimes shifted the attentions of many toward understanding certain questions and challenging problems differently. This can be seen in the proliferation of articles, essays and books written on the subject that appear across most of the sciences including biology, geology, ecology, physiology, the neurosciences, psychology, mathematics, computer science and currently emerging technologies. These approaches are also appearing in the social sciences, education, urban studies, economics, organizational studies, politics, the military and healthcare.[6] This chapter is intended to illuminate some of the historical developments behind a collection of ideas, principles and conceptualizations related to the complexity sciences, or in the language of mathematics, non-linear dynamics.

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[4] A version of this chapter has been published. Darren Stanley, "Paradigmatic Complexity: Emerging Ideas and Historical Views of the Complexity Sciences," in *Chaos, Complexity, Curriculum and Culture*, ed. William Doll, M. Jayne Fleener, and John St. Julien (Peter Lang Publishing, 2005).

[5] Manuel De Landa, *A Thousand Years of Nonlinear History* (New York: Zone Books, 1997), 15.

A few key ideas lie at the heart of complexity science studies. Many writers, scholars and researchers will allude to notions like non-linearity, chaos, complexity, self-organization, self-similarity, scale invariance, emergence, order and disorder, bifurcations, fractals, systems, parts and wholes, variability and so on. These terms are frequently used to describe, interpret and understand, and model particular phenomena that are commonly referred to as complex systems. Before launching into an examination of some of the more predominant theoretical framings of complex phenomena, I will take a brief look at the kinds of structures and organizations that could be described as complex and not-complex.

Complex and Not-Complex

As an analytical approach, reductionism has shown itself to be a very useful strategy for, and means to, understanding a wide range of phenomena. Reductionism, as when one views and interprets the world as comprised of isolated and isolatable parts, tends to frame an understanding of the world as separate although not necessarily inseparable from one's self. Non-reductionists, on the other hand, counter that besides the world, there is nothing else: there is only the world. Thus, there is no separation and the world is entirely connected. Ludwig Wittgenstein emphasizes this in the first proposition of his *Tractatus*: the world is all that is the case, and all that happens to be the case.[7] Yet, there is an almost common assumption that many people continue to make about the world:

---

[6] This should not be read as some distinction between the arts and the sciences as to when and how paradigmatic complexity has been taken up. The weaving of complexity-related ideas is, in fact, much messier with its own set of historiographical challenges. Social scientists have used notions like self-organization and emergence long before natural scientists in the late 20th century. *Cf*, David Aubin and Amy Dahan Dalmedico, "Writing the History of Dynamical Systems and Chaos: *Longue Duree* and Revolution, Disciplines and Cultures," *Historia Mathematica* 29 (2002), Julio Ottino, "Complex Systems," *AIChE Journal* 49, no. 2 (2003).

> *It is a natural assumption about the world that it has its being "out there." That is to say, independent of experience, language, etc., the world is what it is ("the 'it' remains"). We may run into various difficulties understanding that world–under names such as illusion, hallucination, ambiguity, unclarity, equivocation, and the like. But these difficulties do not affect the fact that the world has its self-identical being out there, and such difficulties must be struck out of discourse if it is to be true to this being out there. Even in such striking out, the "it" remains, ever self-identical, ever calling for univocal discourse to give it a voice.*[8]

It should be borne in mind that human beings are inseparable from the world. Our bodies are, as Merleau-Ponty describes, both physical-biological structures and experiential-phenomenological structures that bring us into contact with the world, shaped and giving shape to that world.[9] It is not so much, therefore, that we are embedded and constrained by our environment, but that we participate in this relationship of reciprocal specification and selection.[10] "The world," as Merleau-Ponty writes, "is what we perceive."[11] Our own collusion, then, brings us into a complex set of relationships–with our selves, in a self-reflexive manner, and the world. This is the *latus* in "relationship"–a reference to that which is at one's side. It is a kind of a direct connection with the world or even an ecology where the *eco-* or *oikos* is that which is in one's vicinity, as in one's household. Perhaps, then, in a manner of speaking, it is also through one's "mindset" of the world that one becomes disconnected from the world through particular conceptualizations of that world. Thus, a different mindset that draws one's attentions to the presence of various kinds of connections might give one cause to be suspicious of any kind of cutting up of the world that one might do.

---

[7] The exact quote in German is: "Die Welt ist Alles, was der Fall ist." – "The world is all, that is the case." Quoted in Gordon C. F. Bearn, *Waking to Wonder: Wittgenstein's Existential Investigations*, ed. George R. Lucas, *Suny Series in Philosophy* (Albany, NY: State University of New York Press, 1997), 47.

[8] David W. Jardine, *To Dwell with a Boundless Heart: Essays in Curriculum Theory, Hermeneutics, and the Ecological Imagination*, ed. Joe L. Kincheloe and Shirley R. Steinberg (New York: Peter Lang, 1998), 20.

[9] Maurice Merleau-Ponty, *Phenomenology of Perception* (New York: Routledge, 1962/1996), xvi.

[10] Francisco J. Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991), 174.

[11] Merleau-Ponty, *Phenomenology of Perception*, xvi.

One might argue, in addition, that the world is already and always complex as might be suggested by the various kinds of connections or relations that are present in the world. Moreover, a person's perceptions of the world are already complicitous in and create a sense of complexity-at-work, as reflected in the various and diverse perspectives and ideas that humans bring to one another in conversation, for example. It is, in fact, a *conceptual* sense of the world as a complex phenomenon or entity that is of importance in this work, and it will be explored here as a particular paradigmatic view–one which has not always been the case. Science and society at large, as such, are bearing witness to what would appear to be a new phenomenon, a particular intellectual orientation.

Historically, the 20th century has seen a shift towards a science of complexity prompted by a realization that there are different phenomena appropriately described as "complex," although there are also other phenomena that do not fit into such a class owing to other attributes and dynamics. The complexity sciences are a relatively new, emergent "field" and a transdisciplinary movement among researchers and scholars that originally came together around the realization that there are different kinds of dynamic phenomena which call for different interpretive and descriptive frames.[12] Warren Weaver, an early cyberneticist and information theorist, was among one of the first prominent scientists to question and address on a formal level differences in the dynamics of different phenomena. In a seminal 1948 paper, Weaver outlined three different phenomena, relevant to this section, that have attracted the interest of many other scientists since then.[13]

Although no longer used, Weaver signaled an important early distinction among three kinds of different dynamical patterns which he termed "simple," "disorganized complexity" and "organized complexity." Framed in the language of systems, "simple systems" were thought of and discussed in terms of small numbers of independent parts or variables that determine the system: these include single-body projectiles, planetary orbits, and generally many mechanical systems where the parts and the interactions of those parts are well-defined. As such, the analytical tools available to Enlightenment thinkers like Newton and Galileo proved to be sufficient to understand and model such phenomena.

Eventually, scientists and mathematicians encountered or created more complicated systems where the number of interacting parts or variables used to understand or model the system was increased slightly. Mathematician Henri Poincaré serves as an example of one individual who met up with the intractability of working with some apparently simple systems that fell outside the realm of computability, as when he considered the now famous "three body problem."[14]

---

[12] It may not be strictly correct to identify the "complexity sciences" as a field or a "branch of inquiry" as Brent Davis and Elaine Simmt remind us, suggesting instead that they are best thought of in terms of objects of study rather than modes of inquiry. Without taking too much liberty in the use of the word "field," here I use it in the sense of an "area" of shared activity. In this case, the shared activity involves a study of similar kinds of objects. *Cf.*, Brent Davis and Elaine Simmt, "Understanding Learning Systems: Mathematics Education and Complexity Science," *Journal for Research in Mathematics Education* 34, no. 2 (2003): 137.

[13] Warren Weaver, "Science and Complexity," *American Scientist* 1948.

In the 19th century, as individuals considered systems with increasingly larger numbers of interacting parts or variables, the need for special analytic tools became necessary. Thus, new analytic tools were introduced with statistical instruments and the use of probabilities coming into prominence during this time. Weaver described these kinds of dynamical systems as "disorganized systems." These tools were quite different from the tools of Newtonian mechanics. Whereas the earlier tools from Newton's and Galileo's times were appropriate for describing the interactive dynamical parts of some phenomenon, statistical and probability tools and instruments provided "pictures" of the global behaviours of a system with numerous independent agents or parts.

As various systems became more complicated, individuals needed to rely more upon macro descriptions of these systems when the analysis of large numbers of agents in interaction proved computationally impracticable and sometimes impossible. This movement also coincided with the need for standardization of various industrialized processes and products. These statistical tools subsequently were imported into domains like education, and remain quite familiar to individuals in the social sciences where such phenomena often continue to be analyzed as disorganized complexity in spite of not being the case.

---

[14] Henri Poincaré was not the first person to examine this problem. In fact, in Newton's *Principia*, the third book of his work presents a case for the study of a specific instance of the three-body problem involving the sun, moon and the earth, "admitting no facile solution." A. Rupert Hall, *The Revolution in Science, 1500-1750*, 3rd ed. (New York: Longman Scientific and Technical, 1983), 318.

The problem is that other kinds of phenomena that stretch across a wide range of organizational structure, including physiological systems, various social collectivities, and cultural and ecological phenomena, are not examples of disorganized complexity at all, but are what Weaver originally described as "organized complexity." Such "complex" systems, like classrooms or the workplace, the nervous system or traffic jams, do not easily "surrender" to those analytic tools that were originally designed to interpret chance events or statistical distributions of traits across populations or qualities of standards for large aggregates of machine parts. In fact, complex systems such as these marked a big break that came about upon realizing that certain systems are volatile and unpredictable because they have a capacity to modify themselves or adapt.

Today the terms "simple" and "disorganized complexity" are not so prominent and have been reduced to the concept of "complicated" systems, and the term "organized complexity" has been reduced to "complexity." "Complicated," therefore, is now used in today's more contemporary discourses to refer to events involving individual or collective independent actions, and this includes both simple and disorganized complex systems, whereas, "complexity" generally corresponds to "organized complexity."[15]

As a way of framing the remaining sections, a collection of theoretical frameworks that generally fall under the umbrella term of "complexity" will be considered: not intending to be exhaustive, these include and will be limited to chaos theory, catastrophe theory, self-organized criticality and complex adaptive systems.

---

[15] M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon and Schuster, 1992).

Under the Complexity Umbrella: Chaos

Human beings tend to notice the accidental or even catastrophic more so than the subtle changes that are constantly unfolding. Fitting for an introduction to chaos theory, one such "accident" in the late 1950s is told about MIT meteorologist, Edward Lorenz, who discovered quite by accident a particular quality which is now referred to as "**sensitivity to initial conditions**."[16] His "discovery" in the history of the complexity sciences is often taken to be a critical marker and an often told story in the evolution of chaos theory. Actually, it was an old idea which suddenly emerged in mathematics, physics and **information theory**.

At the time of this story, Lorenz was using some sophisticated linear methods to model weather systems on his Royal-McBee LGP-30 computer.[17] The story of Lorenz's work is told in his own book, *The Essence of Chaos* (1995), as well as in James Gleick's well-known popular science book, *Chaos* (1988).[18] More specifically, both texts describe Lorenz's experience which led to his discovery that small differences in initial conditions could be amplified over time through computational reiterations, leading to more chaotic behaviour and a picture that could suggest a lack of periodicity. The story about this discovery describes how a set of calculations, which were being computed, was suddenly interrupted at one point. Lorenz started the calculations over again except this time used some truncated initial values. After a coffee break and about an hour of printing from his dot-matrix printer, Lorenz returned to find that the numbers on his printout were nothing like his previous computational run. At that time in history, it was not unusual to think that a computer hardware glitch had happened, but Lorenz took a closer look at the numbers and realized that something else was happening. The problem proved to be the initial round-off errors that were amplified in the on-going calculations of the program: thus, the field of theoretical chaos was born–but, not quite.

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[16] Further bold-face words as they appear in this text from this point onward are indicators of further semantic elaboration in the glossary at the end of this work.

[17] Kathleen T. Alligood, Tim D. Sauer, and James A. Yorke, *Chaos: An Introduction to Dynamical Systems* (New York: Springer-Verlag, 2000), 359.

[18] James Gleick, *Chaos: Making a New Science* (New York: Penguin Books, 1988), Edward N. Lorenz, *The Essence of Chaos* (Seattle, WA: University of Washington Press, 1995).

Although the allure of chaos would not take off until others took notice of Lorenz's work and the arrival of computers in the 1960s, the French mathematician Henri Poincaré (1854-1912) can certainly be counted upon as one of the early pioneers who rebelled against the strong presence of Newtonian determinism in a non-linear world. In fact, Poincaré's 1879 doctoral dissertation paved the way for thinking about the formulation of (non-linear) solutions to particular systems of differential equations.[19] His mathematical methods, moreover, proved to be very useful in his solution to the problem of the stability of the solar system, but in particular, his insights opened the door to the study of "**deterministic chaos**."

A well-known and often discussed feature of chaotic structures, as previously mentioned, is their "sensitivity to initial conditions." To be sure, others have not always embraced such sensibilities: LaPlace, for example, suggested that if one knew everything about the starting conditions of the world, the unfolding of the world could be predicted. He writes:

> *Given for one instant an intelligence which could comprehend all forces by which nature is animated and the respective situations of the beings which compose it–an intelligence sufficiently vast to submit these data to analyses–it would embrace in the same formula the movements of the*

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[19] Howard Whitley Eves, *An Introduction to the History of Mathematics*, 6th ed. (Fort Worth: Saunders College Publishing, 1990), 571-72.

> *greatest bodies and those of the lightest atom; for it, nothing would be uncertain and the future as the past, would be present to its eyes.*[20]

Poincaré, on the other hand, suggested something quite different. His often quoted phrase, "*Prédiction devient impossible*," expresses this notion of "sensitivity to initial conditions" in this way:

> *If we knew exactly the laws of nature and the situation of the universe at the initial moment, we could predict exactly the situation of that same universe at a succeeding moment. But even if it were the case that the natural laws had no longer any secret for us, we could still only know the initial situation approximately. If that enabled us to predict the succeeding situation with the same approximation, that is all we require, and we should say that the phenomenon had been predicted, that it is governed by laws. But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible, and we have the fortuitous phenomenon.*[21]

This phenomenon, more recently, has been expressed metaphorically as a butterfly flapping its wings in some part of the world and affecting the weather conditions in another part of the world. The persistent use of this metaphor has created a certain amount of uncertainty about its origins. Nevertheless, Edward Lorenz's 1972 paper, "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?" appears to mark and tends to be associated with the first appearance of this image.[22] Hinging chaos to the condition of sensitivity to initial conditions, however, still does not help much in determining whether or not a system is chaotic.

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[20] I am indebted to Brent Davis for pointing out this quote by LaPlace. Pierre de LaPlace, *A Philosophical Essay on Probabilities*, trans. F. W. Truscott and F. L. Emory (New York: Dover, 1814/1951), 3.

[21] Henri Poincaré, *Science and Hypothesis* (London: Walter Scott Publishing, 1905).

[22] Lorenz, *The Essence of Chaos*, 14.

Mathematically speaking, a chaotic system must be viewed from a macroscopic point of view. Chaotic systems exhibit particular qualities which can be described by features which are called **attractor basins** or **attractor sets**: these are forward-time limit sets of trajectories that attract a significant number of initial conditions.[23] Such attractors include structures known as "fixed-point limits" (Figure 1), "periodic orbits" (Figure 2), and "pathological monsters" known as "strange attractors" or "chaotic attractors" (Figure 3). Thus, it is perhaps more important to attend not to individuals points or localized trajectories, but regions of the chaotic system.

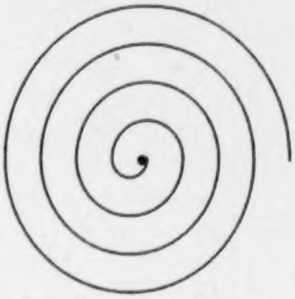

Figure 1: Fixed-Point Attractor

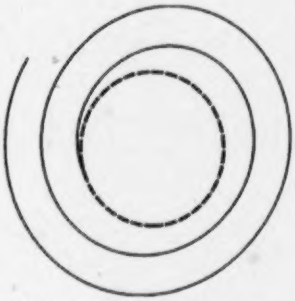

Figure 2: Periodic Orbit Attractor

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[23] Alligood, Sauer, and Yorke, *Chaos*, 240.

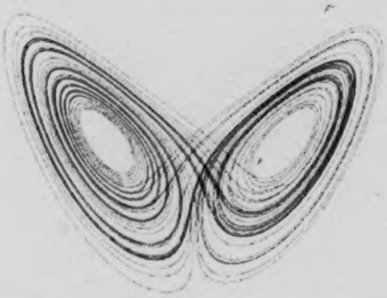

Figure 3: Strange Attractor (Lorenz Attractor)

Focusing on how small changes in the initial conditions might change the outcome of a system is not enough to identify a system as being chaotic. In fact, not all systems are chaotic. As we will see, there are some systems that can unfold in very dramatic (or not so dramatic) ways with small (or even no) changes in the initial conditions. Examples of such systems include "complex systems" and "self-organized critical systems" (which will be described later). Since all systems are not chaotically deterministic, small changes in the dynamics of the system can change the system in a variety of different ways. Changing the interactions of a complex system, for example, can create the possibility for new, novel patterns. For a chaotic system, by simply changing the initial conditions, the local trajectory in time may change, however, the over-all macro-description of the system does not. That is, there can be no possibility for a pattern other than the one that is already inscribed in the system.

It is for this reason that chaos theory is not an entirely appropriate frame or collection of tools that can be applied to human systems or organizations of social interactions: organizations of social interaction are not deterministic. It is not so much that the mathematical tools are bad or outmoded. It is more toward the idea that they are the right tools for another kind of problem.

That is, phenomena with chaotic attractor sets are important for particular qualities that do appear across particular kinds of organized structures. As such, it does make sense then to ask what chaos looks like in such structures.

Images of Chaos

In the age of the "new science," chaos and complexity have brought new perspectives to the ways in which we frame, understand and act in the world. This new perspective has extended beyond the technical achievements of science as well, moving into the realm of the arts, literary theory, philosophy, education and politics with new voices emerging from a post-modernist perspective. Moreover, a whole new sense of ordering is emerging: it is not the older symmetrical, simple and sequential and predictable ordering of a world, but rather something a bit more "fuzzy."[24] Asymmetry, chaos and "fractal" forms are the "new order" of the day.

This is not to suggest that the shared sensibility of chaos is the same across levels of discourse let alone are identical with the mathematical sense of chaos. It, most assuredly, is not. The colloquial notion of chaos is quite different from the technical, mathematical sense of chaos. This difference in interpretation can be problematic as it can make for challenging conversations where the same words may be used but convey different senses or meanings. Still, it can be very difficult for some individuals to be open to other possibilities for understanding chaos. Put differently, natural scientists may be skeptical of certain uses of chaos theory, and find some non-scientific perspectives that invoke chaos theory to be questionable.[25] At the same time, other "non-scientific" approaches, for example post-modernist approaches, challenge the privileged nature of science where it might be implied that certain meanings of "chaos" are better or more accurate.

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[24] William E. Doll, *A Post-Modern Perspective on Curriculum* (New York: Teachers College Press, 1993), 3.

[25] Peter Weingart and Sabine Maase, "The Order of Meaning: The Career of Chaos as a Metaphor," *Configurations* 5, no. 3 (1997): 465.

The late-20th century has seen some rather interesting and prominent shifts within the larger social collective. That is, after centuries of trying to straighten out the world, "new scientists" and "post-modernists" have moved towards an attempt to embrace the kinkiness of the world. There is, in fact, a certain natural, universal aesthetic preference for irregularity and roughness that human beings have: it is capturing the imaginations of scientists and artists alike.[26] The language and concepts attributed to the domain of complexity science, like "fractals" and "chaos," are popping up everywhere from the interpretations of Jackson Pollock's abstract paintings involving paint drippings to computer graphics, music and other wonderful strange attractions.[27]

The topic of "**fractals**" is a common one in complexity-related discussions and post-modern discourses. These patterns of chaos with common signatures like cracks and crevices, fractures and fragments, and wrinkles and warpings are a part of the "new aesthetic" for artists and scientists. There is a particular beauty about fractals and a certain perfection in their imperfections. The concept of a fractal has permeated into a larger collective understanding of the roughness and kinkiness of the world, its energy, and its capacity for transformation and dynamical change.[28] That is, when one peers deeper into the structure or process of some phenomenon one might see scales of organized structures that bear a certain resemblance with structures at other scales. This pattern is called **self-similarity** or more generally, **scale invariance**.

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[26] Branka Spehar et al., "Universal Aesthetic of Fractals," *Computers and Graphics* 27, no. 5 (2003).

[27] Ary L. Goldberger, "Chaos Theory and Creativity: The Biological Basis of Innovation," *Journal of Innovative Management* 4, no. 3 (1999), Spehar et al., "Universal Aesthetic of Fractals.", Richard P. Taylor, A. P. Micholich, and D. Jonas, "Fractal Analysis of Pollock's Drip Paintings," *Nature* 399 (1999).

In a Euclidean world, one might experience a discontinuous jump of sorts from the single dimension of a straight line to the two-dimensions of a plane figure to the three-dimensions of a solid object and so on. Fractals, on the other hand, are often described as "things" that lie in between these dimensions, and thus they are objects with fractional dimensions, depending on the nature of their crinkliness or crumbling nature. For example, space-filling curves as an iterated process, like Poincaré's 2-dimensional space filling monster (Figure 4), serve well to highlight how a one dimensional process might give rise to a 2-dimensional object as well as Sierpinski's triangle (Figure 5), an object with an area between 1- and 2-dimensions. Nature, therefore, shows itself to us across many different scales, as opposed to levels, where "evolutionary activity creates worlds within worlds, all moving, changing, feeding back into each other from small scale to larger scale, back to small scale."[29] Taken to either extreme–the very small and the very large, as well as everything in between and beyond–the whole and part play out in this image of scale-invariant detail, always a whole and a part in the wholeness of an all-at-once world.

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[28] John Briggs, *Fractals: The Patterns of Chaos; a New Aesthetic of Art, Science, and Nature* (New York: Simon and Schuster, 1992), 23.

[29] *Ibid., 41.*

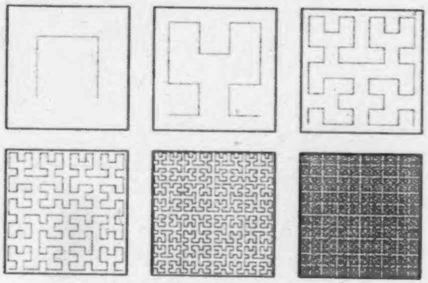

Figure 4: Poincaré Space-Filling Curve

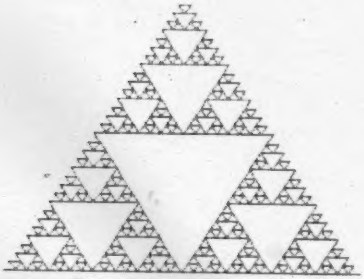

Figure 5: Sierpinski Triangle

Last, it would be good to pay attention to an important distinction between chaos and fractals. To be certain, they do share some common ideas and methodological approaches.[30] Deterministic chaotic equations can generate particular images in a mathematical object called a "phase space": when the image is said to be fractal, the corresponding time series is referred to as chaotic. But, as James Bassingthwaite and his colleagues remind us, "objects and processes studied by fractals and chaos are essentially different."[31]

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[30] James B. Bassingthwaighte, Larry S. Liebovitch, and Bruce J. West, *Fractal Physiology* (New York: Oxford University Press, 1994), 138.

[31] *Ibid.*

When it comes to the growth of fractals and chaotic behaviour, various formal iterative processes have been introduced. In 1968, a biologist by the name of Aristid Lindenmayer invented a mathematical description for plant growth which has become known as the L-system.[32] It is a production system which takes an axiom, a rule or set of rules, and re-iteratively applies the rules over and over until an ever more complex, recursively defined symbolically represented object appears. Not only does this process work for describing and creating tree- and fern-like objects, but space-filling curves and objects like the Sierpinski triangle can also be constructed. In addition to Lindenmayer's L-system, fractals can also be created using affine transformations, that is, through a combination of four linear transformations known as translations, scalings, reflections, and rotations which describe how to create and position miniaturized versions of an original object.[33] Unlike the L-system, affine transformation fractals can be described in a single composite matrix and created in a single step rather than through a set of iterations. Mathematically speaking, through **recursion,** fractals and chaotic behaviours can emerge. Recursion has a way of elaborating a pattern in time or space, which in its looping, is vastly different from the linear, accumulative nature of many other objects which modern science generally describes.

As previously mentioned, fractals have a particular quality called self-similarity whether these are objects or processes: analysis of possible fractal data is intended to determine whether or not this feature of self-similarity is present. Where this quality of self-similarity is present, appropriate fractal tools can then be used to characterize the dataset. In the case of chaos, however, one is concerned with knowing whether a given dataset is the result of a deterministic process which can then be analyzed for and expressed in terms of a set of non-linear equations. Where this is not the case, the time series dataset would suggest uncorrelated randomness–the lack of some correspondence between observed empirical data and a clearly defined process. For example, a healthy person's heart rate, expressed as a time-series, should be fractal in nature; however, in the case of atrial fibrillation, the measured dynamics is expressed as randomness.

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[32] Gary William Flake, *The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation* (Cambridge, MA: MIT Press, 1998), 78.

[33] Ibid., 93.

A number of notions have been discussed so far as they pertain to chaos-related phenomena. Other kinds of dynamical phenomena show characteristics not found in chaotic structures. The notion of "suddenness" and the concept of discontinuous change, for example, are not captured in a chaos theoretic framework. In the history of the complexity sciences, other conceptual frames have been proposed that draw one's attention to this notion and nature of "change." Two conceptual frames in particular that address change in this particular fashion are **catastrophe theory** and **self-organized criticality** which will be discussed in the next section.

Change and Opportunity: Crises, Catastrophes and Criticality

How do people conceive and perceive of change? Is "change" dramatic? slow to appear? all of a sudden? progressive? It is, perhaps, both evolutionary and revolutionary, and both can be seen at work in nature. Catastrophes and moments of crisis, in more usually-taken-for-granted ways, tend to mark occasions of change: they are dramatic and all of a sudden, often "catching us off guard." But, of course, things like our bodies, the seasons or the mountains change, too, albeit much more slowly and sometimes imperceptibly so.

Change would appear to be a process that unfolds across many different temporal scales. A Chinese garden, for example, is a fitting illustration of a place where one might observe change happening across many such scales. Without much attention to the details of a Chinese garden, one might miss how the careful and deliberate framing of Nature presents itself to us in the patterns of change: the turbulence of the water fall; the blossoming of the Winter Jasmine flower; the stillness in the shadows of the trees caressing the white walls, moving gently across the open courtyard with the sun above; the rigid rocks with their life-like qualities that stare back in the shapes of oddly recognizable, familiar forms.

A Chinese garden, when viewed for its beauty and splendor, might not be the image that comes to mind as a place where catastrophes or crises happen. It does, however, bear a similar aesthetic quality to other fractal objects and processes. But what gets noticed and how it is noticed in terms of change is strongly shaped by our own perceptions. Those things that fall below our threshold of perception appear stable and unchanging: above such a threshold, a world of change appears. That is, the world appears as changing at some times and not at others rather than a constantly changing world.

A "catastrophe," as its etymology suggests, is a "turning" of some kind–like the "turning away" of a letter by the insertion of an apostrophe in a word; the turning over of a new leaf as when one changes one's behaviour, throwing away an old one; or turning the corner to go in some new or different direction. A "turning point," therefore, appears and throws into question a certain prevailing view–it can be a moment of crisis, or metaphorically, a crack in some foundation. A catastrophe, of course, need not imply throwing out one entire thing for another. In more post-modernist sensibilities, a catastrophe may simply be about the opening up of other possibilities for additional consideration.

Let us consider the notion of change, from a slightly more technical scientific perspective, as explored in and described by the work of mathematicians, René Thom and Christopher Zeeman.[34] Challenging the notion that change happens gradually, they framed their ideas in what they called "catastrophe theory" which examines the changes in the state-space of a system that describe sudden discontinuous transitions. In other words, catastrophe theory offers a mathematical description for how the sudden dynamical changes in a system happen when the system moves from one state to a radically different state without passing through any intermediate states. The nature of the jump, with its suddenness and discontinuity, makes it a "catastrophe" or a kind of **bifurcation point** between attractor sets.

What kinds of phenomena qualify for such a mathematical description? Mathematical catastrophes are void of any emotive content, and as such, describe sudden changes in the state of a system that may or may not have the desired outcome.[35] For example, changes in water from its solid to liquid form or from liquid to vaporous form are illustrative of the kinds of changes that have been explored through the mathematical framework of catastrophe theory. Other examples have been explored which look at the turbulence of water, the buckling of iron girders like those found in high-rise buildings or bridges, heart beat dynamics and predator-prey models.[36]

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[34] René Thom, *Structural Stability and Morphogenesis: An Outline of a General Theory of Models* (Reading, MA: W. A. Benjamin, 1975), E. C. Zeeman, *Catastrophe Theory: Selected Papers, 1972-1977* (Reading, MA: Addison-Wesley, 1977), E. C. Zeeman, *Lecture Notes on Dynamical Systems* (Aarhus: Aarhus Universitet, 1968).

[35] D. S. Jones and B. D. Sleeman, *Differential Equations and Mathematical Biology* (London: Allen and Unwin, 1983), 267.

Although Zeeman and Thom's work in the 1970's and 1980's marked the most important period of work on catastrophe models in terms of popularity, these kinds of models continue to show their influence on the scientific world's sense of change. In fact, catastrophe theoretic models continue to be used and explored today in the social and natural sciences, however, not with the same fervor.[37] In evolutionary terms, one might say that it is dying out, although there are traces of its being in the ideas of other complexity-related concepts.

While the notion of a catastrophe is no longer prominent in the mathematical sense, it has been superseded by the concept of "criticality," as in Per Bak's "**self-organized criticality**."[38] Bak, the man who coined the term, suggested that complex interacting dynamical systems, under certain conditions, could automatically adjust themselves to a state characterized by power-law correlations in both space and time. [39] That is, there is no characteristic length or time scale that describes the behaviour of the system.

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[36] T. Poston and I. Stewart, *Catastrophe Theory and Its Applications* (San Francisco: Pitman, 1978), D. Ruelle and F. Takens, "On the Nature of Turbulence," *Communications in Mathematical Physics*, no. 20 (1971), E. C. Zeeman, ed., *Differential Equations for the Heart Beat and Nerve Impulse*, vol. 4, *Towards a Theoretical Biology* (Chicago: Aldine Publishers, 1972).

[37] *Cf.*, *e.g.*, the journal *Nonlinear Dynamics, Psychology, and Life Sciences* continues to publish articles on catastrophe-related models of complex phenomena. Generally speaking, however, mathematical researchers have opted for the more general framework of "bifurcation theory" instead of "catastrophe theory."

[38] Per Bak, *How Nature Works: The Science of Self-Organized Criticality* (New York: Springer-Verlag New York, Copernicus, 1999), Per Bak, Chao Tang, and Kurt Wiesenfeld, "Self-Organized Criticality: An Explanation of 1/F Noise," *Physical Review Letters* 59, no. 4 (1987).

[39] Per Bak died in October 2002.

Of the many terms that fall under the complexity umbrella, "self-organized criticality" (SOC) is an exciting and relatively recent concept to appear. It is intended to convey a sense of on-going change across many scales; under the same underlying dynamics, it also can bring forth big changes where the history of an entire system is affected. The canonical examples that are often raised in this context are sand piles and earthquakes.[40] The idea has also spread to other phenomena like electrical breakdowns, magnetic flux, water droplet formations and more recently to biological evolution. In each case, the basis for change is suggested by the idea of self-governance of the system itself and its own internal dynamics–self-organization.[41]

Sand piles, the canonical example of SOC, demonstrate how sprinkling grains of sand over the top of a sand pile can produce a growing sand pile and sand avalanches of various "sizes."[42] After an avalanche, the system returns to a moment of stability. By continuing to add grains of sand, the sand pile hovers around this critical point, approaches instability when sand grains topple down the sides, and then regains a temporary state of stability. This critical state is self-organized. That is, the sand pile naturally approaches this state of criticality without any kind of intervention, and it is not designed into the system. Moreover, the sizes of the various avalanches follow what is described as a **power law** where small avalanches are quite common and large ones are rare. They come in all sizes.

Since the appearance of chaos and catastrophe theories and self-organized criticality, a number of other ideas and concepts have come into play–

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[40] Henrik Jeldtoft Jensen, *Self-Organized Criticality: Emergent Complex Behavior in Physical and Biological Systems*, ed. P. Goddard and J. Yeomans (Cambridge: Cambridge University Press, 1998), 2.

[41] Although external forces frequently contribute to the evolution of the system, such processes happen more slowly than the internal processes that tend to relax the system. Ibid., 3.

[42] Flake, *The Computational Beauty of Nature*, 334-35.

complex adaptive systems, network theory, diffusion theory, artificial neural networks, complex responsive processes, systems thinking, and so on [see glossary for further elaboration and clarification]. The similarities and differences are much too vast for such a short chapter as this. Many complexity-related ideas that are discussed in the various literatures of today are being taken up in greater earnestness: in terms of a conceptual frame, a theory of complexity could never formally capture any "suitably complex" phenomena. Nevertheless, human beings are facing a time of immense opportunity for framing and enhancing a much richer view of the world than has been seen before.

Certainly, the complexity sciences have called for a re-evaluation of how we might understand and explain social interactions. We should not think, however, that this shift will improve our "social organizations." Nevertheless, there are some individuals and organizations who are attempting to use complexity science concepts to try to create the kinds of conditions for particular outcomes or arrangements in various social settings. To help see how some concepts that are used in the complexity sciences might be useful for thinking about learning and teaching, broadly speaking, including classrooms and schools, the next chapter will be useful for setting up a frame for understanding some of the conceptual underpinnings behind some of the complexities of social organizations. Specifically, the next chapter explores some key concepts relevant to complex adaptive systems or, simply put, complex systems.

Chapter 2

COMPLEXITY PRINCIPLES AND FEATURES

Characteristics of Complex Systems

> *Science has begun to try to understand complexity in nature, a counterpoint to the traditional scientific objective of understanding the fundamental simplicity of laws of nature. It is believed, however, that even in the study of complexity there exist simple and therefore comprehensible laws. The field of study of complex systems holds that the dynamics of complex systems are founded on universal principles that may be used to describe disparate problems ranging from particle physics to the economics of societies.*[43]

The world is stunningly complex. Complexity can be found on so many different scales. Atoms. Molecules. Organic compounds. Cellular structures. Tissues. Organs. Organisms. Species. Societies. Economies. Ecosystems. The world is a complex place, indeed.

I frequently wonder, sometimes in great amazement, how beautifully complex the world is. Trees, interestingly enough, continue to fascinate me and for me bear certain similarities to different aspects of human beings as well as other complex entities. For one day a week over a period of more than a year, I traveled between Toronto and Oakville on the GoTrain. The ride was, in part, time to relax and an escape from the city if only for a half day. I always looked forward to my weekly excursions and getting lost in the scenery–in particular, the trees.

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[43] Yaneer Bar-Yam, *Dynamics of Complex Systems* (Reading, MA: Perseus Books, 1997), xi.

With apologies to Gertrude Stein, one might think that a tree is a tree is a tree.[44] But like roses, no tree is like any other tree–certainly never identical to another. Nevertheless, each tree is recognizable as a tree, but how could I account for the differences amongst the many different kinds of trees as well as the changes I saw over time? The more that I began to read about complexity science, the more I began to appreciate the beauty of trees and the creative possibilities that emerged over many different time scales. Moreover, for me, the trees started to suggest ways in which social systems might emerge. It was perhaps with my attention to trees on these trips to Oakville that I started to make connections with classrooms and schools, I would presume, since my trips to Oakville were to work with a cohort of 90 pre-service elementary school teachers.

What I have learned is that there are some phenomena in the world that are more fitting of a complexity frame rather than, say, a mechanical understanding. Certain concepts and tools have come to show how much more useful they can be in my own understanding of complex, living organizations. Thinking about the kinds of conditions needed for healthy learning organizations, for example, has gradually opened up some alternative ways of thinking about a variety of different aspects of education, including the dynamics of classrooms and schools.

Human beings frequently refer to various features of the world as being simple or complex, clear or messy, straightforward or complicated. In this chapter, I will address a collection of features and aspects of complex phenomena, organizations and learning. In particular, the notions of non-linearity, emergence, self-organization, diversity, interactions, redundancy and fractals will be taken up in the context of an emergent field of study referred to as the complexity sciences.

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[44] Stein's exact quote is "Rose is a rose is a rose."

Non-Linearity

The concept of linearity surfaces in a number of different guises and distinct contexts where meanings of the idea differ slightly although overall abstractions are quite similar. Two properties, in particular, are frequently invoked: the **property of proportionality** and the **property of independence.**[45] Framed in the language of systems theory, for example, a system or process is linear if the output of some operation is directly proportional to the input, and if the input is allowed to vary, then the output will also vary predictably by some constant of proportionality. That is, there can be no possibility that a small change in the initial conditions could lead to something dramatic.[46]

In terms of visual metaphors, linearity is also often expressed in the form of a straight line on a Cartesian plane. In this manner, a particular phenomenon or event is often discussed as if it flowed or unfolded along a line. "Time" and "change," for example, are most often conceived as relentless "motion" along linear pathways. It is probably inevitable then that human beings would frame and understand events as linear happenings. But most of the world is not that straight since in a world of complex patterns, a capacity to adapt to a changing world requires a non-linear being; in fact, herein lays the importance of being non-linear.

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[45] Bruce J. West, *An Essay on the Importance of Being Nonlinear* (New York: Springer-Verlag, 1985), 5.

[46] More generally, if several factors are implicated in some system or process, then it is said to be linear if the end result is proportional to each factor. Mathematically speaking, it follows that each constant of proportionality is independent from one another. In other words, if $x_1, x_2, \ldots, x_n$ are n variables which determine the value of some outcome or value for a dependent variable, y, where $y = c_1x_1 + c_2x_2 + \ldots + c_nx_n$, then y is a linear function if $c_1, c_2, \ldots, c_n$ are independently determined.

The concept of a straight line can be interpreted in a number of different ways: algebraically, geometrically or parametrically, for example. A straight line also constitutes a set of ordered points, an arrangement of points. Historically, this was not always the case.[47] Prior to the discretization program of mathematics in the late-19th century, the concept of a line was quite different and suggested that lines were *not* composed of points. Lines were whole continuous objects in space. With the appearance of a point-set topology, the notion of a line (in spite of how it is experienced as a continuous object) then was conceived as an ordered set of points. As a result, a notion of "betweenness" emerged.[48]

With this notion of arranging and ordering points, as in a row, the idea of a sequence is not too far away. In more "post-modern" times, there is a sense that linearity is synonymous with order. Thus, there is this notion that events in the world can, should or tend to unfold in a particular sequence. A non-linear approach, therefore, is one that seemingly goes against a presumed, usually-taken-for-granted order. For instance, on one occasion, a presentation I attended was structured and ordered by the throw of a die as the presenter wished to do a non-linear presentation. This kind of mixing up of things, however, should not be taken for being non-linear as this is a randomizing process. Random processes are not non-linear processes as they tend to involve independent events. Here, in this example, some coherence is lost in the meaning of "non-linearity," and some misunderstanding is created with inappropriately imposing a particular mathematical idea onto certain aspects of existence.

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[47] George Lakoff and Rafael E. Núñez, *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being* (New York: Basic Books, 2000).

[48] Freundenthal, for example, discusses briefly this notion of "betweenness" as when a person cuts a piece of string (*i.e.* an arc) into two pieces. He writes: "On an arc there is a natural concept/between;/*b* between *a* and *c* if by the cut at *b* the points *a* and *c* get into different pieces." Herein lies the related notion of "order." The concept of non-linearity does not have this sense of betweenness and hence order. *Cf.*, Hans Freudenthal, *Didactical Phenomenology of Mathematical Structures* (Boston: Reidel Publishing, 1983), 259.

On Recursion and Non-Linearity

As far as non-linear processes are concerned, "recursion" tends to play a significant part. Recursion, suggesting a "re-writing," takes some element (*e.g.*, a number or computed value) and applies a rule to some element to create a subsequent element in an on-going process. Snowflakes tend to be one of my favourite examples of a recursive process at work. Through the dust in the atmosphere, temperature gradients, moisture in the air and the molecular structure of water, snowflakes take formation in a recursive play of being and becoming. Recursive processes, therefore, have a way of transforming what is given into something that is possible. This happens when human beings, and especially children, play and are being creative. Dampening non-linear processes tends to squash possibility and creative emergence.

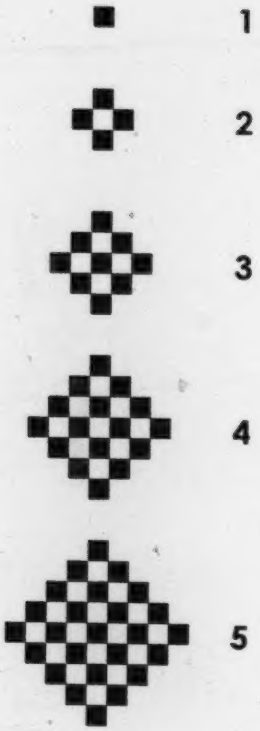

Figure 6: Recursion and Growth

Although far from being a snowflake, it is useful to present an example of recursion in the form of Figure 6.[49] There may, in fact, be many ways of describing the successive checkered objects as they are shown here with the intention that further iterations will give rise to larger forms. The nature of a recursively-defined object requires an object for transformation and a set of rules that are to be applied to the object. To begin, a "seed" or initial object is required: in this case, it is object #1. The object is then transformed through a rule or set of rules. In this case, object #2 represents the generative rule which is applied to object #1. More explicitly, the four squares directly adjacent to the sides of the initial black square are filled in and the initial black square is removed. In subsequent iterations (the next one is object #3), the same rule (expressed visually as step #2) is applied to *each* of the black squares. In this manner, the object is re-written, seemingly as a whole, but not. The re-iterative process is applied to each "part" of the object, and on a local-level co-emerges with and into a larger coherent whole.

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[49] For further examples of recursion, Stephen Wolfram's popular work on cellular automata has many more wonderful complex examples. Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Media, 2002).

On Emergence

Since the use of concepts like chaos and fractals, other popularized concepts have become just as familiar to a larger audience, largely drawn from a scientific perspective, although elements of a philosophical and theological bent have also been invoked. As an example, the concept of "**emergence**" is finding a new and exciting place in analytic thought, promising new ways in which to think about how novelty can happen in a very old universe.[50] As Harold Morowitz suggests, emergence is the opposite of reduction. He writes:

> *The latter [reductionism] arises from the whole to the parts. It has been enormously successful. The former [emergence] tries to generate the properties of the whole from an understanding of the parts. Both parts can be mutually self-consistent.*[51]

A broad search, particularly of work referred to as the "complexity sciences," reveals an intense fascination with the phenomenon of "emergence," its characteristics, and the conditions under which novel events present themselves.[52] As Jeffrey Goldstein notes, the history of the term goes back to the 19th century when pioneer psychologist G. H. Lewes used the term to describe a particular chemical process that was different from "resultant" chemical processes, although to be certain, the underlying idea was stated by Aristotle almost 2000 years ago in his *Metaphysics*.[53] Emergence has become a predominant notion in the complexity literature: it has a certain ubiquity and importance that is largely understood through numerous lists of illustrated accounts.[54] It is a notion that seems to be difficult to define–like the notion of the complexity sciences–eluding those who wish to observe it through the persistent patterns across a number of different disciplines.

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[50] Harold J. Morowitz, *The Emergence of Everything: How the World Became Complex* (New York: Oxford University Press, 2002).

[51] *Ibid., 14.*

The notion of emergence seems to be a frequent quality of many features and phenomena in the world. Still, the concept of emergence has had a diverse conceptual existence: mechanical engineer, Seth Lloyd, from MIT has compiled a list of more than 30 different definitions for emergence.[55] Yaneer Bar-Yam, in addition, raises a red flag about some troubling misunderstandings about emergence. He writes:

> *For many, the concept of emergent behaviour means that the behaviour is not captured by the behavior of the parts. This is a serious misunderstanding. It arises because the collective behavior is not readily understood from the behaviour of the parts. The collective behavior is,*

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[52] Jeffrey Goldstein, "Emergence as a Construct: History and Issues," *Emergence* 1, no. 1 (1999): 49.

[53] Peter A. Corning, "The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory," *Complexity* 7, no. 6 (2002): 18-19, Goldstein, "Emergence as a Construct," 53.

[54] John H. Holland, *Emergence: From Chaos to Order* (Reading, MA: Perseus Books, 1999), 3.

[55] John Horgan, "On Complexity and the End of Science," *Complexity* 2, no. 2 (1996): 14.

> *however, contained in the behavior of the parts if they are studied in the context in which they are found.*[56]

In other words, through local emergence, collective behavior begins to appear in and from the smaller parts of the system that can manifest a global emergent behavior. The "scale" of observation, therefore, is important to understand the notion of emergence.

Put differently, a bird is not a flock, a car is not a traffic jam, and a person is not a riot. In each of these cases, there are different scales of organization. Schools, as complex phenomena, are also interesting examples of the embedded multi-scale nature of complexity which encompasses the student and teacher, to the dynamical patterns of the classroom and the patterns of the school community itself. Moreover, they co-exist in their embeddedness in a context of always and already on-going interactions. Distinct, but not inseparable, emergent phenomena like a flock, a traffic jam, classrooms are the result of local interactions, which, by themselves, cannot tell us what might be possible on other scales.

In terms of learning, cognition, and social interaction, the pitting of the individual and the collective is a frequent happening, particularly in certain educational discourses.[57] Over the most recent of times in the field of education, a variety of different learning theories have emerged that focus on either the individual or the collective. Even more, treatments of either one of these units of analysis, however, have not necessarily resulted in similar understandings as with, for instance, behaviorism or mentalism and radical constructivism. On the other hand, radical constructivism and social constuctionism, while they may focus on different phenomenon, do have some things in common, particularly as holistic, organic or ecological theories of learning. As more holistic theories, the theoretical framings are more toward the relational. What might be useful, therefore, to keep in mind here is that the underlying dynamics are about dependency rather than determinacy–proscribed rather than prescribed action. As such, the actions or possibilities of any one "whole" (as in a single person or a single group of people) can exceed the actions of the improvising "parts" that give rise to the myriad of possibilities for that whole.

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[56] Bar-Yam, *Dynamics of Complex Systems*, 10.

[57] Brent Davis, Dennis J. Sumara, and Rebecca Luce-Kapler, *Engaging Minds: Learning and Teaching in a Complex World* (Mahwah, NJ: Lawrence Erlbaum, 2000).

Emergent phenomena are hard to measure or explain since they lack a certain concreteness that might be useful for recognizing it when one might see it.[58] The variability and possibilities for emergent phenomena, therefore, make it quite difficult, if not inappropriate, to apply statistical tools for measurement purposes (like testing). As Goldstein suggests: "Emergence functions not so much as an explanation but rather as a descriptive term pointing to the patterns, structures or properties that are exhibited on the macro-scale."[59] In terms of the breadth of coverage, the notion is described and defined, for example, in the writings of physicists, organizational theorists, economists, and philosophers to describe a variety of different phenomena like convection patterns, the formation of network patterns, the behaviour of the stock market and consciousness.

There is nothing particularly mysterious about the way in which new phenomenon emerge. Certainly the behaviour of a collective can defy the capacity of a person's ability to predict such outcomes. But how emergent behaviour and patterns happen is not particularly magical. Simply put, a collection of agents acting in concert, following a collection of simple rules, can bring forth a dynamic behavioral form that cannot be found at the level of the individuals in the system.

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[58] Corning, "The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory," 22.

[59] Goldstein, "Emergence as a Construct," 58.

It might be tempting to think that the interacting parts or agents of a system are akin to mere abstract particles. In fact, they need not be unless, perhaps, they are virtual agents in some would-be world. Still, the world is replete with nested emergent phenomena–emergent phenomena arising from emergent phenomena arising from emergent phenomena, and so on. As Goldstein says:

> *In effect, there seems to be no end to the emergence of emergents. Therefore, the unpredictability of emergents will always stay one step ahead of the ground won by prediction. [...] As a result, it seems that emergence is now here to stay.*[60]

In other words, the parts may be just as complex as the system of which they are a part. Thus, there are other levels of emergence that may arise within a given system that potentially serve to make for more unexpected events. But more importantly, and perhaps more appropriately, different scales of organization are related or linked to one another by virtue of a shared collection of dynamics.[61]

It seems quite fitting at this point to be reminded of the commonly invoked phrase: "Complex systems are more than the sum of their parts." The "more" here is not used in an additive sense as the statement tells us that emergence is not simply a matter of taking into consideration all of the

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[60] Ibid.: 60.

[61] Personal communication from Scott Kelso.

"parts" (no matter how simple or complex they might be) and the interactive nature of each improvising part. The sense of "more" is more "productive" rather than "additive." Even the "and" in the phrase "parts *and* interactions" is somewhat problematic. It clearly is not a logical operator. Emergence is really something else!

As far as the playful intellect goes, the possibility of new organizations or phenomena can emerge through more than just parts or agents interacting with another. Agents in a system can change through adaptation, that is, through "the act of bending a structure to fit a new hole."[62] An adaptation involves a structure changing itself, as its etymology suggests, to "fit" with the changing surroundings. As Robert Axelrod and Michael Cohen write: "In systems we call adaptive the strategies used by agents or a population change over time as the agents or population works for improved performance."[63]

Whether one is concerned with a flock of birds, a swarm of ants, a weather system or a game of SimCity, their emergence represents what Bar-Yam refers to as a "level of description of the world."[64] He continues:

> *A level is an internally consistent picture of the behaviour of interacting elements that are simple. When taken together, many such elements may or may not have a simple behaviour, but the rules that give rise to their collective behaviour are simple. We note that the interplay between levels is not always just a self-contained description of one level by the level*

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[62] Kevin Kelly, *Out of Control: The Rise of Neo-Biological Civilization* (Reading, MA: Addison-Wesley, 1994), 340.

[63] Robert Axelrod and Michael D. Cohen, *Harnessing Complexity: Organizational Implications of a Scientific Frontier* (New York: Basic Books, 1999), 18.

[64] Bar-Yam, *Dynamics of Complex Systems*, 292.

> *immediately below. At times we have to look at more than one level in order to describe the behaviour we are interested in.*[65]

Emergence as some "push into novelty" arises at the boundary of what Stuart Kauffman calls the "adjacent possible."[66] Although Kauffman uses this term to express the emergence of what could happen next in the context of a chemical reaction, the term would also seem to aptly express the possibilities for what might happen next for any emergent phenomenon. The space of the adjacent possible is never fixed, and while a complex system may be viewed as rule-bound and constrained, this does not imply that the adjacent possible is known and knowable. As Kauffman writes:

> *Note that the adjacent possible is indefinitely expandable. Once members have been realized in the current adjacent possible, a new adjacent possible, accessible from the enlarged actual that includes the novel molecules from the former adjacent possible, becomes available.*[67]

Not all large systems, however, display emergent properties. Consider a system with a lot of interacting parts, such as, for example, the molecules of a balloon. There are a great number of molecules interacting with one another, independently so, but still there is no possibility for emergent novelty. To be sure, most definitions of complex systems suggest that a large number of interacting parts is necessary, a system can exhibit complex behaviours and still have relatively few interacting parts. The famous "three-body problem" is a fitting example of such a phenomenon, although it is still more toward the chaotic rather than the complex where the phenomenon is a collection of three deterministic trajectories. Even still, although there are only three interacting bodies, their interactions with one another create a set of novel emergent trajectories. It is, therefore, not necessarily the number of interacting-agents involved in a given phenomenon, but the relations and interactions that bring forth a new, emergent form.

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[65] Ibid.

[66] Stuart A. Kauffman, *Investigations* (New York: Oxford University Press, 2000), 142.

[67] Ibid.

Bar-Yam notes that a system with too many parts or components can be a problem for researchers studying or modeling complex systems.[68] Too many components, even if there may be large numbers of interactions, can result in an emergent form of behaviour that may be perceived as uniform in nature. Thus, in an ambiguous sort of way, a complex system must have "just enough" but "not too many" parts. For instance, the interactions of molecules in an air-filled balloon suggest something complex; however, it is more chaotic (in the everyday sense of the word) than anything. There are lots of interactions, but they are far too many and definitely do not give rise to any emergent forms. To understand this sort of disorganized complexity or complicatedness, one can only generate various statistical measures.

In addition to the notion of emergence, complex phenomena also exhibit another quality referred to as **self-organization**. In the following section, the relation between emergence and self-organization will be explored.

Self-Organization

The term "self-organization" has also proven to be a frequently invoked term in the complexity-related literature. Self-organization describes how a system may bring itself into being on its own with a minimum of external direction or assistance. Kevin Kelly refers to this sort of process as "bootstrapping."[69]

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[68] Bar-Yam, *Dynamics of Complex Systems*, 5.

[69] Kelly, *Out of Control*, 450.

Self-organization is not a new concept: one can go back to what now are called the "Macy Conferences" to find scientific researchers like Gregory Bateson, Norbert Wiener, Margaret Mead, Warren McCulloch and John von Neumann engaged in lively conversation and debate over the notion of "self-organizing systems." The 1959 conference is of particular note with its primary focus on self-organization.[70]

Where self-organizing patterns are visible, the descriptions of the phenomenon cannot be deduced from the individual interacting parts of the systems to account for features that can only be observed at the level of the self-organized whole. In other words, the behavioral complexity of self-organizing systems depends on interactions, and not its individuals or parts.[71] Moreover, the type and variety of interactions have a great deal to do with the behaviour of the emergent system.

In a large system, individuals within it have no global idea how to build a collective organized structure. An ant, for instance, has no idea how the ant colony is taking shape. Moreover, depending on the environment, the same collection of interacting agents–ants, cars, people, for example–can create a variety of different emergent patterns. Nevertheless, the same agents in the system can and do interact with one another without some key organizing figure to bring forth, in a self-organizing manner, continuously generated novel forms. For this reason, a variety of widespread self-organized forms and universal patterns appear in the world even though, for example, no two trees, two flocks, two rivers, two cities, two brains are ever the same.

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[70] *Ibid., 451.*

[71] Ricard V. Solé and Brian C. Goodwin, *Signs of Life: How Complexity Pervades Biology* (New York: Basic Books, 2000), 176.

Self-organization is a term that is generally applied to a wide range of processes, giving rise to patterns that emerge within physical and biological systems.[72] As previously mentioned, some believe that a minimum of external direction is sometimes applied: one might call this *weak self-organization*. A corollary to this notion would suggest that *strong self-organization* would imply no external assistance or direction being applied to the system under consideration. In other words, the actions of each participating agent in the system are well-defined where all are interacting locally in some kind of mutual understanding. Frequently discussed examples–virtual and otherwise–tend to include ants and ant colonies, termites and wood chip mounds, and birds and flocks.[73] Human beings also self-organize under different conditions and for different reasons. Stand on the corner of a busy street and watch people cross at the crosswalk. In moments of crisis, thousands of people can self-organize to create what is needed in the moment. Demonstrators, for instance, use cell phones and other technologies to converge upon a potential demonstration site.[74] Political acts of this nature are not the only kinds of self-organizing social phenomena that can happen in this fashion: disaster relief projects, for instance, have been known to unfold in a similar manner.[75]

Of course, not all processes or approaches to carrying out some task are self-organizing in nature. Templates, recipes, lesson plans or blueprints, for instance, are sometimes taken to be prescriptive approaches to carrying out some required task: that is, there is no self-organization present. But, to be clear, there is not always the need for self-organization; prescription is not necessarily a bad thing. It is the situation that would seem to matter.

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[72] Scott Camazine, *Self-Organization in Biological Systems* (Princeton, NJ: Princeton University Press, 2001), 7.

[73] Flake, *The Computational Beauty of Nature*, 261-75.

[74] Howard Rheingold, *Smart Mobs: The Next Social Revolution* (Cambridge, MA: Perseus Pub., 2002).

[75] Howard Rheingold refers to this as "smartmobbing disaster relief," referring to the tsunami which struck many countries in the southern hemisphere from Indonesia to Africa in 2005. (www.smartmobs.com).

In the context of education, for example in classrooms and school settings, it is sometimes said that people experience school life *as if* they were like machines, functioning in rather prescriptive ways. Lesson plans are presented as templates to be filled in. Curricula are written as isolated and isolatable chapters of topics and concepts intended to be presented as sequentially explored matters. Learning is normalized with classroom averages calculated, and schools compared by subject at the end of each school year. Subjects are treated as if they were as insular as the classroom walls of each group of students. These matters would seem to suggest that self-organization does not play much of a role in such a setting that treats learning, teaching and knowing as already known phenomena. Put differently, as part of the normative discourses of schooling, it does seem that the complexities of schooling tend to be reduced to a functionalist form of socialization where teaching and learning are sometimes presented as prescriptive approaches.[76]

The concept of self-organization has become an important notion in discussions of how complex phenomena might emerge. Moreover, self-organizing phenomena seem to unfold without being particularly prescriptive: larger collections of local interactions of improvising agents acting in concert have the capacity to collectively produce something much bigger than any one of them. In addition to the concept of self-organization, another concept plays an important role in the emergence of complex phenomena: diversity.

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[76] Deborah P. Britzman, *Practice Makes Practice: A Critical Study of Learning to Teach* (Albany, NY: State University of New York Press, 1991), 56.

Diversity

Concerning the complexity of the relations that various kinds of organizations bring to bear, the notion of "diversity" is an important one to consider. As a structural (product) and dynamic (process) property across many scales of organization, diversity is an essential concept that should be pursued in any discussion about complex phenomena.

Discussions on diversity are quite common within and between various discourses on organizations–schools, the workplace, families, and communities, for example. A great deal often is said about respecting the diversity of an organization. This, however, does not always happen. Some diversity is considered good, but some people may believe that being open to all kinds of diversity is neither permissible nor acceptable–not in social organizations anyway. In this manner, diversity is imagined as something to be managed or controlled, a problem to be overcome or, at best, tolerated. Whether viewed as a means to make matters more just or to respond to the changes in one's environment, for complexity scholars and others diversity in these contexts is implicitly understood to be a challenge that must be addressed for the purposes of legitimacy or meeting the novel circumstances of one's context.[77]

In terms of social systems, or the ways in which human beings organize themselves for particular purposes or reasons, diversity is not simply a matter of sex, gender, race, language, ability, and so on, but also speaks to other matters.[78] The implications for work in the school classroom are a good example here with a "typical" mathematics classroom providing us with a number of useful examples of how difference and diversity are dealt with. In a classroom where prescription tends to direct the actions and possibilities for thinking about doing mathematics, a diversity of views or problem-solving approaches is sometimes viewed as something to be corrected so that the actions of the class and the teacher remain "on track." In a system viewed for "productivity," getting side-tracked in the classroom in this manner is seen as being unproductive: to be sure, this might not be good for a system when viewed in terms of being a machine. Viewed differently, in a classroom where difference and diversity are "respected," possibilities can be amplified, dampened or make no change to the dynamics of the classrooms. As most teachers will tell us, the best laid plans are still open to the unexpected. I, for example, have suddenly found myself talking about other areas of mathematics that were not supposed to be a part of the planned class for that day, discussing concepts like complex numbers, orders of infinities and counting with large sets, and fractals. Clearly, in spite of my best attempts, the attention of the classrooms in which I have taught have managed to diverge, slightly or otherwise, from what I had intended. As my own experiences in the classrooms would suggest, the presence of an authority figure, *i.e.*, the teacher, can certainly affect the dynamics of a classroom, but cannot determine the direction of a classroom that functions in a more holistic sense.

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[77] Reuben R. McDaniel and Michelle E. Walls, "Diversity as a Management Strategy for Organizations: A View through the Lenses of Chaos and Quantum Theories," *Journal of Management Inquiry* 6, no. 4 (1997): 363.

Diversity, generally, cannot be handed down or imposed "from above." But, to be sure, it is always present even when one might conceive a social organization or system as homogenously given or pre-determined. This perception of a system as being rigid or machine-like is not entirely unwarranted. It speaks to the nature of how "connected" we might be with one another. And, the nature of these relations arises from the interactions, which give rise to other interactions, creating self-organizing and self-organized patterns of relations.

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[78] The term "diversity" is a term invoked widely across the educational literature in very specific ways. In this work, however, I have explicitly taken the term from the complexity science literature which suggests something more toward the idea of "variability."

Relations, Connections and Interactions

As far as emergent phenomena go, should one speak of relations, connections or interactions? Perhaps some other term would be better? Thus far, complexity science has spoken largely of "interactions" as being one of the necessary conditions for the possibility of a self-organizing phenomenon. Etymologically speaking, the notions of an agent or an actor are closely related to the word "action." Still, the notion of an action or act as "doing" something might suggest something that is a fully conscious, autonomous actor–something human or human-like. This is unnecessary. It could be said, for example, that virtual automata bring forth new emergent forms, but they are not human nor do they really interact with one another.

For an organization to emerge, then, agents need not come into direct physical contact with one another. Different kinds of animals use flocking, swarming and schooling techniques for a variety of different purposes.[79] Flocks of birds, for example, emerge without physically touching one another, relying upon other kinds of cues instead. Ants often rely upon pheromones to self-organize for purposes of foraging, finding a new home or attacking predators. Fish, similarly, travel together in ways that seem to benefit the entire school. Visual cues, chemical gradients, auditory signals and other tactile indicators all seem to serve these organizations in one way or another.

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[79] Edward Osborne Wilson, *Sociobiology: The New Synthesis*, 25th anniversary ed. (Cambridge, MA: Harvard University Press, 2000).

While emergence may not require some sort of physical contact or touch, for the parts of a system to bring forth some novel form, each of the "players" in the system certainly must be "close enough" to one another. They need not rub up against one another, but they must somehow stand in relation to one another and connected in some fashion. Although, the notion of a relation suggests a "carrying back" to something, as in one's ancestral or family relations, the words "relate" or "relation" closely resemble the word "lateral," as something that is situated on, directed toward, or coming from the side.

For some final thoughts here, one might suggest that interactions are fundamental to emergent patterns. As Ralph Stacey writes: "Interaction is understood to construct further interaction in processes that pattern themselves."[80] Human beings cannot regulate themselves in isolation from the world: they require other human beings, coming into contact with one another, forming relationships. Such notions require a re-iteration of interaction with one another; in so doing, an emergent sense of "connectedness" or a "relation" emerges. Put differently, relations are a matter of survival for human beings, a part of human evolution.[81]

Axelrod and Cohen speak of two different types of interactions: internal and external.[82] Although still open to debate, Axelrod and Cohen believe that social systems are not closed systems. For this reason, positing two distinct types of interactions seems unnecessary. Every organization and its agents have relations that are already embedded in a much larger context–other families, communities or neighborhoods, municipalities and other settings of state. Thus, internal and external interactions are relations arising from a dynamic that brings forth a variety of different emergent forms. In other words, the interactions themselves shape the emergent patterns in temporal processes that manifest a variety of patterns within and across an organization. Moreover, a diversity of interactions, through a non-uniformity of agents prompting one another, is a necessary mechanism for a complex system to emerge.

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[80] Ralph D. Stacey, *Complexity and Group Processes: A Radically Social Understanding of Individuals* (New York: Brunner-Routledge, 2003), 17.

[81] Ibid., 22-23.

[82] Axelrod and Cohen, *Harnessing Complexity*, 62.

Redundancy

Like its early roots suggest, a redundancy is an "overflow." Redundancies are excesses of the kinds of features that might be necessary for a particular phenomenon to happen. Redundancies, therefore, seem to serve as a guarantee that some aspect of a system can continue to exist and function without there being a crucial element missing from the system. In addition, in a highly redundant system, mistakes and errors can happen and the system can still continue as many other existing possibilities (of choice of action, say) will still be available to and for the system.[83] Put differently, redundancy is characterized by more than simple excesses: the concept of redundancy points to the innumerable possibilities for fulfilling some given function of interest.[84]

Unfortunately, the notion of redundancy is associated with those aspects of a system that are not necessary, contributing to inefficiency. On the contrary, in the context of complex systems as with learning in general, redundancy is an important feature of such systems that allows them to function independently of specific relations and protect them from danger or loss. Instead of some possibility of failure, redundancy offers a certain measure of security where multiple structures can stand in the place of one another for their functional equivalence.

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[83] Niklas Luhmann, *Social Systems* (Stanford, CA: Stanford University Press, 1995), 60.

[84] Ibid., 172.

Redundancy is also not simply about the replicative nature of an organization. There is also a "generative" quality that redundancy brings to an organization.[85] That is, instead of a replication of parts or people, the redundancy lies in the complex patterns of organizational ties or relations. Where there is redundancy of relations in an organization, if a particular tie becomes broken, other relations can be enacted to get around problems or blockages. It is in this manner that an organization is generative: the organization re-generates itself around damaged relations, becoming more innovative and adaptable to change.

A number of structures have been studied that show how redundancy can fill a wide range of purposes as with, for instance, the way that various technologies can be used to communicate with others during times of crisis; the ways in which the nervous and circulatory systems of the human body function; and, the idea of conversation even is sometimes viewed as a way of eliciting related states or resonating ideas in another person's mind.[86] What is most important here is that, in each of these cases, there is an important conceptual structure at work. That is, these organizations bear a certain geometrical structure called a fractal. In the final section of this chapter, the notion of fractals is discussed as a common feature of complex organizations.

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[85] John Kelly and David Stark, "Crisis, Recovery, Innovation: Responsive Organizations after September 11," (New York: Center on Organizational Innovation, Columbia University, 2002), 1528.

[86] Ibid. Ary L. Goldberger, "Fractal Variability Versus Pathologic Periodicity: Complexity Loss and Stereotypy in Disease," *Perspectives in Biology and Medicine* 40, no. 4 (1997), Ary L. Goldberger et al., "Fractal Dynamics in Physiology: Alterations with Disease and Aging," *Proceedings of the National Academy of Sciences (Online)* 99, no. 1 (Suppl.) (2002), Tor Nørretranders, *The User Illusion: Cutting Consciousness Down to Size* (New York: Viking, 1998).

Fractal Forms and Processes: An Embodiment of Complexity Principles

The topic of fractals is a common one in complexity-related discussions and discourses. Fractals are complex patterns that are a part of the "new aesthetic" for artists and scientists. There is a particular beauty about them and a certain perfection in their imperfections with images of cracks and crevices, fractures and fragments, and wrinkles and warps as the more common signatures or canonical examples of fractal form. The concept of a fractal has permeated into a larger collective understanding of the "roughness" and "kinkiness" of the world.[87]

In as much as human intrusions attempt to straighten and flatten out details, bumps, deviations, and such, much of the world and its features are not easily measured with the kinds of tools, *e.g.*, rulers, protractors and compasses, readily available for more "classical" forms. Certainly, many human-made structures are easy to measure and describe with all of the usual-euclidean metrics, however, as Mandelbrot tells us: "Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightening travel in a straight line."[88] That is, instead of attending to the actual form, connecting the dots between a collection of points or snapshots, say, a certain ignorance of the always-changing form arises.[89] In other words, where Euclidean geometry pushes the notions of linearity and knowability, fractal geometry, as a concept and as its history shows us, announces plenty of turns and surprises along the way.

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[87] Briggs, *Fractals: The Patterns of Chaos*, 23.

[88] Quoted in Flake, *The Computational Beauty of Nature*, 93.

One only needs to look closer or step back a bit to see the presence of many kinds of details at different scales. Fractal geometry is the geometry of complex phenomena: it is the geometry of life. As Gleick reminds us, fractal geometry "mirrors a universe that is rough, not rounded, scabrous, not smooth. It is a geometry of the pitted, pocked, and broken up, the twisted, tangled, and intertwined."[90] In other words, the essence of complex phenomena, as manifest through the geometry of fractal forms, are not so much blemishes and pitfalls to be overcome, but the "real thing"–living things, complex things. That is, where euclidean geometry seems quite fitting for the fixed and given; fractal geometry serves the flexible and emergent.

When one looks deeper into or pulls back just a bit from the structure or process of some complex phenomenon, one can't help but notice the presence of many different scales of detail. Sometimes, it is possible find a certain byzantine-like architecture of similar structures with each level of magnification. That is, like a tree with its branches, smaller limbs and twigs, and the veins of its palmated-leaves, scales of organized structures that bear a resemblance to one another can be found across many different scales: thus, the larger tree looks like a smaller limb with the smaller limbs and twigs on it. This kind of pattern has a degree of **self-similarity** where the same kind of pattern can be found across a number of different scales or levels. In addition, more generally speaking, a complex phenomenon shows **scale**

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[89] Brent Davis and Dennis J. Sumara, "Curriculum Forms: On the Assumed Shapes of Knowing and Knowledge," *Journal of Curriculum Studies* 32, no. 6 (2000): 822.

[90] Gleick, *Chaos*, 94.

invariance which is the ever-presence of detail–of bumps, folds, graininess, and so on–across many scales of the phenomenon all-at-once.

Taken together, self-similarity and scale-invariance suggest that fractal forms announce a kind of nestedness of complex bodies. Conceptually and metaphorically speaking, these bodies manifest themselves in forms which include biological subsystems, the biological body, social collectivities, the political state, the world of evolved species, and the larger ecological body or ecosphere.[91] But complexity not only allows one to see complex nested structures, but complex processes and interactions as well. In other words, studies of the processes and forms of complex bodies-in-action are providing researchers and scholars with another collection of images and metaphors to understand a wide range of complex phenomena. Some further comments and elaborations will be made in the next chapter on fractals, where I will draw upon a few examples from studies of complex fractal physiological forms and dynamic processes.

It should be borne in mind that these principles and features of complex systems are but a small set of possible concepts used to describe and understand life's complexities. As to their suitability for describing and understanding human interactions within social contexts, a number of problematic issues arise that will be discussed later. Nevertheless, in the next chapter, a number of complexity principles will be presented with the aim of comparing different kinds of complex organizations by attending to their underlying dynamics. In so doing, the notion of "health" will be introduced to highlight how the fundamental relations of a given organization might give rise to strikingly different dynamic patterns–patterns of "healthiness" and "unhealthiness."

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[91] Davis, Sumara, and Luce-Kapler, *Engaging Minds.*

Chapter 3

COMPARATIVE DYNAMICS[92]

Toward a View of Healthy and Unhealthy Dynamical Patterns

> *The prospect of a new millennium provides a welcome challenge to educationists to throw off these conceptual constraints in the search for a new vision appropriate to the challenges of a second industrial revolution. It is the unique privilege of comparativists to straddle cultures and countries, perspective and topics, theories and disciplines. Thus we have a particular responsibility to carry the debate beyond the discussion of means alone. And towards ends.*[93]

In this chapter, a new conceptual term will be introduced: "comparative dynamics."[94] Following other branches of comparative inquiry like "comparative anatomy," "comparative literature," "comparative education," *etc.*, the notion of "comparative dynamics" is intended to compare the dynamics of different kinds of phenomena.

A "comparison," as the word suggests, involves a "likening" of things where qualities or characteristics are drawn upon to highlight similarities or differences between things with the aim of showing certain relative values or qualities. The other term, "dynamics," of Greek origin, is about power and strength: that is, it pertains to forces that produce motion or make something happen. As a branch of physics, therefore, dynamics addresses the relation between the forces or interactions of a system and the ways in which the patterns of the system change or transform themselves.

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[92] A version of this chapter has been published. Darren Stanley, "The Body of a 'Healthy' Education System," *Journal of Curriculum Theorizing* 20, no. 4 (2004).

[93] Patrica Broadfoot, "Comparative Education for the 21st Century: Retrospect and Prospect," *Comparative Education* 36, no. 3 (2000): 370.

[94] Although the notion of "comparative dynamics" is new, the ideas behind it stand in relation to the history of systems dynamics theory which, for simplicity, can be linked with the early ideas to emerge from general systems theory from the 1940s. Those ideas can be found in the previous chapter wherein I touch upon, for instance, notions such as non-linearity, recursion and feedback.

The focus of a comparative dynamics approach, thus, is on the dynamics of a phenomenon and on the similarities and differences of dynamical patterns that arise from within a given organization of dynamical patterns.[95] That is, comparative dynamics is a systemic comparison of similarities and differences *at the level of the dynamics and dynamical patterns* within a particular *kind* of phenomenon. The kind of phenomena of interest here need not be restricted to "complex" phenomena, but what must be kept in mind is the need to compare patterns from the same kind of phenomena. That is, the comparison should be between complex systems, or simple systems with simple systems, and so on. This chapter focuses on the dynamics embodied in patterns of complex systems.

The emergence of this term, comparative dynamics, arose somewhat unexpectedly near the end of writing my dissertation. I cannot pretend to know exactly how and why this term came about. I can surmise, however, that there were two factors at work which may have contributed to its invention. To begin, it seemed obvious to me that what I and others have been thinking and talking about involved comparisons and analogies across different kinds and scales of organization, comparing bird flocks with termite colonies, human riots with bee swarms, and earthquakes with the lived-experience of surprise, for instance. This alone was not enough for me to invent a new term.

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[95] R. Darren Stanley, "The Body of Education: What Might a 'Healthy' Education System Look Like?" (paper presented at the Complexity Science and Educational Research Invitational Conference, University of Alberta, Edmonton, AB, 2003).

In addition to the kinds of comparisons that individuals make to try to understand what complex systems are, my conversations with medical professionals and my on-going reading raised an interest in healthy physiological systems. The term "healthy," of course, is a bit subjective, but what I was noticing was the presence of particular dynamics and dynamical patterns that were observed when different physiological systems were described as being "healthy."

The introduction of this term, therefore, has emerged from a realization that under certain conditions, the dynamics of a particular phenomenon might give rise to dynamical patterns that could be described as "unhealthy" or "healthy." These terms are already used in more popular parlance to describe fragile human relationships during divorce, sick ideas and toxic workplace environments.[96] The notion of an organizational dynamic described as "healthy" or "unhealthy" can be illuminated through the use of examples from the field of human physiology–for example, the physiological organization of the human heart and the human gait. The comparative dynamics of these phenomena can then be extended to other cross-scale complex phenomena, that is, to other scales of organization, including the biological body, bodies of collectives like knowledge, social organizations, cultural bodies, political bodies, the living bodies of different species, and the ecosphere.[97]

Some Historical Roots of Human Physiological Dynamics

The belief and sense that the body functions in an orderly fashion is neither a new nor an uncommon idea. Conventional medical wisdom still suggests that disease and aging arise from the external stresses of the world around us which affect an otherwise orderly and machine-like body. That this view of maintaining a proper balance of bodily functions still exists is a testament to the plausibility of such beliefs which date back to the ancient Greeks and their Near Eastern neighbors. But to be clear, this view is derived from literary sources and a few extant texts on medicine itself.[98]

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[96] Peter J. Frost, *Toxic Emotions at Work: How Compassionate Managers Handle Pain and Conflict* (Boston: Harvard Business School Press, 2003).

[97] Davis and Sumara, "Curriculum Forms."

This view of health as an orderly phenomenon has not always been a shared view. In fact, the concept of health from a Chinese medical perspective has a very long history and one quite different from the "Hippocratic corpus." Traditional Chinese medicine maintains a sense of dynamic equilibrium with a body composed of a network of organs sustained through "human activities of storing and spreading, preserving and transforming, absorbing and eliminating, ascending and descending, activating and quieting."[99] Chinese sensibilities hold that health is about balance and offers no notion of "illness" since this is a Western notion rooted in the measurable, quantifiable entities of a body out of order. Put differently, where the Chinese tend to resonating patterns of harmony or disharmony, there is the tendency for Western medicine to think of a body which approaches illness and disorder as fixing somatic structures that perform particular functions.

The Hippocratic corpus, however, was a very different view of health and well-being from the Chinese view of health, and was a prominent body of writings among the more secular and learned medical traditions of the ancient Greeks. These works emerged alongside the more traditional healing practices of the day, including religious incantations and dream healing.[100] Prominent among the Hippocratic writings are various theories about health and disease. In fact, these treatises often associated disease with some imbalance in the body or an interference with its natural state. If disease were associated with an imbalance of some sort, the required "regimen," once the diagnosis was made, was applied and directed toward restoring the health of the individual to a more balanced state.

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[98] David C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. To A.D. 1450* (Chicago: University of Chicago Press, 1992).

[99] Ted J. Kaptchuk, *The Web That Has No Weaver: Understanding Chinese Medicine* (Chicago, Ill: Contemporary Books, 2000), 75.

In more recent times, this notion of balance in the body has been described in terms of the principle of "homeostasis." Homeostasis, described by Claude Bernard in 1878 as the stability of an organization's structural interior milieu, suggested that the human body was designed so that "concentrations and rates of processes tended toward a stable state, through multiple feedback mechanisms."[101] Researchers, however, are questioning whether this is in fact the body's main mode of operation, opting instead for a view of "homeodynamics" which allows for a more flexible view of how a system might operate in more complex ways under various perturbations even to the extent of inherent *instability*.[102]

Ary Goldberger and his colleagues at Harvard Medical School are discovering some rather counterintuitive findings about the ways in which the human body functions. In fact, their unexpected findings suggest that various physiological systems have a capacity for erratic behaviour when human beings are young and healthy. Moreover, as human beings age or develop certain illnesses, particular systemic behaviours become increasingly regular and ordered. That is, Goldberger has framed a number of physiological systems, connected as they are to one another, according to underlying dynamics and patterns along a spectrum of "healthiness."

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[100] Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. To A.D. 1450.*

[101] Bassingthwaighte, Liebovitch, and West, *Fractal Physiology*, 327.

[102] Ary L. Goldberger, David R. Rigney, and Bruce J. West, "Chaos and Fractals in Human Physiology," *Scientific American*, Feb 1990 1990.

Irregularity and unpredictability, therefore, seem to be important aspects of healthy physiological systems–indeed, for a healthy life. Decreased variability and accentuated or increasingly regular, periodic interactions tend to be associated with–or increase the possibility for–disease and dying.[103] From a complexity science point of view, variability is an often discussed aspect of and condition for dynamic learning organizations like various physiological, social and ecological systems.

Health from a Complexity Science Point of View

The Case for Variability

Variability is not merely an important aspect for healthy physiological systems. It also holds for other "kinds" of systems–across all scales of the biological body, collectives of knowledge, social and cultural organizations, political ideologies and the entire ecological web of life. But not all forms of diversity seem to "win out" or "work" for an organization, and in this case, to be appropriate conditions for an organization to be healthy. This is where complexity science can help clarify why variability is such an important organizing principle for a healthy system.

Variability is not the same as randomness. Randomness is concerned with phenomena or events that are independent of one another. One of the more common examples of such events involves the flipping of a coin. An unbiased coin will land on either a head or a tails. Flip the coin again, and the same thing will happen except there is no relation between the two events.

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[103] Goldberger, "Fractal Variability Versus Pathologic Periodicity."

Statistically speaking, of course, over a long series of coin flips, 50% of the flips will be heads and 50% will be tails. Random events and processes are fine for determining what baseball team hits first; however, in matters of life and death, variability is more important for the interconnectedness of living phenomena.

In the world of interconnectedness, then, the presence of more variability allows for greater responsiveness to the always and already on-going changes that are unfolding across dynamic living organizations. It is not possible, however, for any organization to respond to every possibility. That is, there is a lack of "requisite variety."[104] Nevertheless, through strategies of selection and the exploiting of contingency, the evolution of biological, social and ecological organizations may persist.

Today, "healthy" variability can be understood and even quantified through an increasing growth of concepts and tools introduced by mathematicians and computer scientists that can be applied to biological systems. Medical clinicians and researchers are, thus, finding new ways to quantify and understand the "chaotic" dynamics of human physiological structures and processes. Researchers are finding the help they need in such concepts as fractal geometry, non-linear dynamics and the unifying notion of self-similarity.

Non-Linear Dynamics and Fractal Geometry

Numerous phenomena in nature seem to unfold within a certain logic for predictability, stability and regularity. But, of course, the world is not quite so exact–nothing is exactly periodic in the strict mathematical sense of the word. Nevertheless, the notion of periodicity seems to exert a strong universal urge for human beings. Human beings tend to think that certain natural phenomena unfold in linear or near-linear fashion. But as Schroeder suggests:

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[104] Luhmann, *Social Systems*, 25.

> *Nature abounds with periodic phenomena: from the motion of a swing to the oscillations of atoms, from the chirping of a grasshopper to the orbits of the heavenly bodies. And our terrestrial bodies, too, participate in this universal minuet–from the heart beat and circadian rhythms to monthly and even longer cycles.*[105]

Smooth, predictable, periodic waves, cycles or formations, however, are not the only noticeable processes and structures that are apparent in the world. Aperiodic and highly irregular dynamical processes and patterns can also be seen: these processes and patterns are called "fractals" after Benoit Mandelbrot who invented the term. The Mandelbrot Set (Figure 7) and the Koch Curve (Figure 8) are frequently cited examples of fractals. The world of nature, in fact, is full of irregular structures which show temporal and/or spatial fractal arrangements. As mentioned previously, we find details at all scales of the organization that resemble the organization on other scales, including the entire organization itself.

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[105] Manfred Schroeder, *Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise* (New York: W.H. Freeman and Company, 1991), 1.

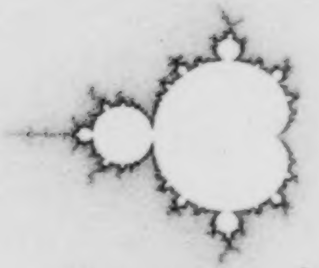

Figure 7: Mandelbrot Set

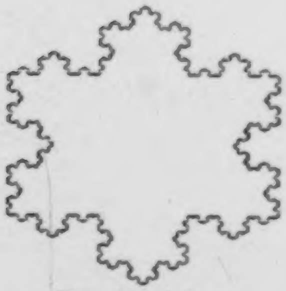

Figure 8: Koch Curve

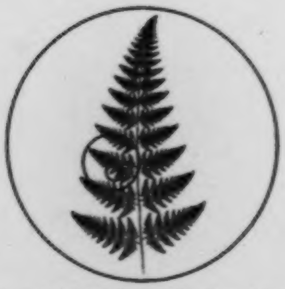

Figure 9: Three Scales of a Fractal Fern

Fractal structures and dynamical systems, like the physiological examples to be discussed shortly, emerge from "non-linear" or "chaotic" processes. These are systems that vary deterministically in time even though they may appear to be random in nature.[106] In other words, these processes may create and suggest a certain amount or kind of variability, but they do not produce random outcomes and events since they are the result of iterative, deterministic processes, whereas random happenings are events that unfold in an undetermined fashion, independent of other events. Human bodies, social bodies, ecological bodies, to be clear, are not independent structures as they are always relational in nature. While it is frequently said that such systems display what is commonly described as "sensitivity to initial conditions," where a small perturbation might bring forth an entirely different trajectory, the overall organization of the structure is maintained. That is, the system is robust enough to maintain a certain identity for itself.[107] This sense of robustness might otherwise be described as "being healthy" or "healthy robustness."

Complex Anatomical and Physiological Structures

The concept of fractal structures provides us with an approach to "describe, measure, model, and understand many objects and processes in living things."[108] Within the human body, the entangled mass of neural assemblies, blood vessels, bile ducts, and tracheo-bronchial tubes in the lungs represent examples of structures which researchers are currently describing as fractal anatomies. Non-linear dynamics can also be found in physiological processes, including: fluctuations in the volumes of breaths, voltage and current changes across cellular membranes, blood flow patterns through the network of coronary arteries to the heart, and the electrical signaling patterns of the His-Purkinje system of neurons that trigger the muscles of the heart to contract.

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[106] Lorenz, *The Essence of Chaos*.

[107] Erica Jen, "Stable or Robust? What's the Difference?" *Complexity* 8, no. 8 (2003).

[108] Bassingthwaighte, Liebovitch, and West, *Fractal Physiology*.

Before the introduction of the concept of a fractal, scale-free structures like the tracheo-bronchial system and heart rate dynamics were tremendously complex to analyze and interpret. Fractal structures are still difficult to identify owing, in part, to the appearance of randomness in some organized structures. Whereas random structures have fluctuations that are governed by mechanisms of chance, chaotic fractal structures are specified deterministically.

Fractal anatomies and non-linear dynamics play important roles in the human body. The branches and folds of fractal physiologies suggest three kinds of functions: absorption, distribution, and information processing.[109] In the first case, the folds of the intestinal tract, for example, serve to significantly increase the amount of surface area for the absorption of nutrients. Physiological structures which serve to collect and distribute materials more efficiently include the tracheo-bronchial system of our lungs for the transportation of oxygen and carbon dioxide to and from the body, and our circulatory system for blood flow throughout the body. On the last function–information processing–the nervous system serves as a complex system of chemical-electrical signaling processes that form the basis for our sensory, motor-neural and cognitive functions. These structures, *per se*, exhibit redundancy and high irregularity, and thus are more robust and resilient to injury or perturbations.

What must be borne in mind, however, is that many anatomical and physiological structures exhibit fractal structures only under those conditions where the system considered might be described as "healthy." When illness or some disease strikes, a person often develops symptoms that are remarkably periodic and predictably ordered. Pathological periodicity rather than fractal variability is the sign of an unhealthy system. In such situations, people with certain diseases show a loss of individual variability. This manifests itself in the appearance of patients who look remarkably like one another with the same pathological dynamics, appearance and form.[110] In terms of fractal anatomies, a loss of structural complexity can be a sign of an unhealthy system or degradation of that structure.

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[109] Goldberger, Rigney, and West, "Chaos and Fractals in Human Physiology," 43.

Comparative Dynamics

A considerable amount of research has unfolded over the past couple of decades where medical researchers have studied the bio-dynamics of a variety of different phenomena. This research has shown how "complex, sophisticated and remarkably sensitive living processes really are."[111] A significant challenge for biologists has been to understand how the complex coordination of structures like cells, for instance, simultaneously arise from the interactions of smaller scale phenomena and participate in the formation of larger scale structures. As previously mentioned, researchers have studied neural assemblies, blood vessels and tracheo-bronchial tubes, the volumes of breaths, voltage and current changes across cellular membranes, blood flow, and the electrical signaling patterns. In the remaining part of his section, aspects of the human heart and gait will be presented as illustrations of health and unhealthy dynamics.

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[110] Goldberger, "Fractal Variability Versus Pathologic Periodicity."

[111] Jan Walleczek, "Frontiers and Challenges of Biodynamics Research," in *Self-Organized Biological Dynamics and Non-Linear Control: Toward Understanding Complexity, Chaos and Emergent Function in Living Systems*, ed. Jan Walleczek (Cambridge, England: Cambridge University Press, 2000).

On the Heart

Healthcare practitioners frequently refer to the seemingly constant, predictable pulse of a healthy person at rest as a *regular sinus rhythm.* Anyone might come to this conclusion when a pulse is taken at the wrist or on the carotid artery under the jaw or with a doctor's stethoscope. The time between beats and the strength of the pulse in a healthy person is generally perceived as more or less constant. In fact, this is not so. For a healthy individual, there is much more variability that can be discerned through more careful empirical measurement.[112]

Although the current medical practice of taking the pulse in this manner suggests that a pulse in a healthy human being, traveling throughout the body in a wave, is regular and sinusoidal in nature as an ECG machine might suggest, it is the dynamics of certain heart conditions that show regular sinusoidal rhythms. To be clear, not all heart conditions display such regular pathological periodicities. Consider the 4 graphs in Figure 10.

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[112] Goldberger et al., "Fractal Dynamics in Physiology."

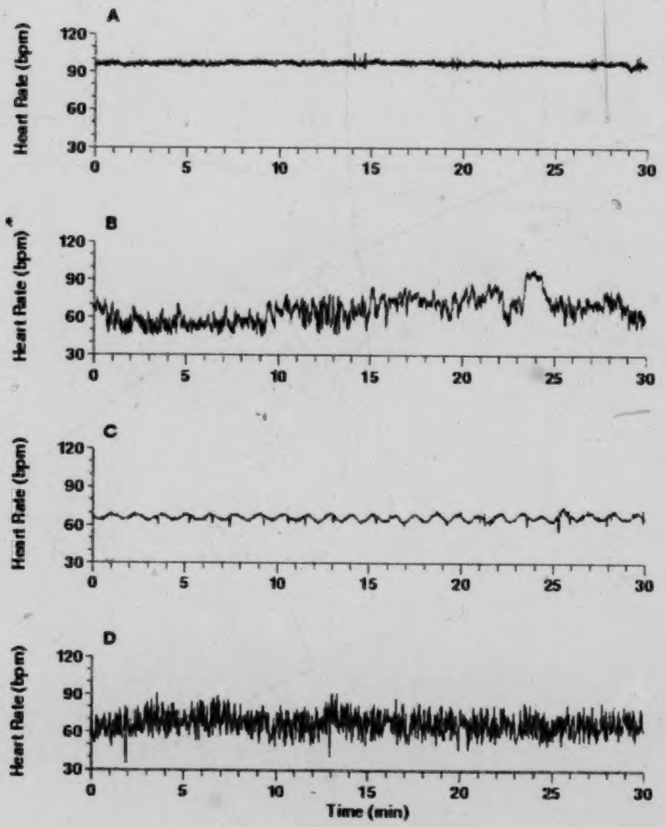

Figure 10: Time series for four representative heart rate recordings

One of these datasets represents the dynamics of a typical healthy individual. The other three datasets are representations of unhealthy individuals. Not all cardiac disorders are identified through stable, predictable periodicities. In fact, one of these datasets represents a disorder known as atrial fibrillation, a severe cardiac arrhythmia–a highly irregular pattern.

Datasets A and C represent sinus rhythms in two different patients with congestive heart failure. Identifying the type of disorders and subtle differences still proves to be a challenge to those in biomedicine. While both A and C are identified with congestive heart failure, the excessive regularity of C also bears the signature of a particular periodic rhythm associated with another disorder known as Cheyne-Stokes breathing, a strong cyclical breathing pattern. This leaves either B or D as the health case example. Both suggest the presence of variability which is not always a good thing. In fact, D is the disorder known as atrial fibrillation, owing to the presence of too much variability. It is excessively erratic and the breakdown in the heart renders the time series with an aggregate of uncorrelated random data.

Dataset B represents an example of the kind of dynamic present in a healthy heart. There is enough variability present, but not too much. The quality and quantity of fluctuations in terms of strength and number across many different time scales is fractal in nature. If one were to examine smaller or larger time scales for similar time series of healthy hearts, the dynamical patterns rendered will suggest a certain self-similarity.

Interestingly enough, I had a very strange experience happen to me during one conference presentation when, after describing the dynamics of complex phenomena, I showed the same graph to the individuals in the room. Somehow I expected that "testing" the room would identify the one and only healthy heart dynamic. Surprise! Not only did this not happen, the choices were uniformly distributed across each of the four choices. Why did this happen? I cannot say for sure as I did not have the time to ask people to respond with why and how they made the choices they made. It does strike me that one reason could be that the possibility that even an *image* of variability will not necessarily convey a "sense" of variability and even a particular *kind, e.g.,* fractal.

On Human Gait: “Walking the Talk”

When underlying physiological control mechanisms change, shifting parameters into critical ranges, sudden qualitative changes in dynamics can result. This is the hallmark of a “dynamic disease.”[113] The previous example with the heart shows a number of multi-stable dynamic patterns which include congestive heart failure and atrial fibrillation. Studies on the human gait have also shown how neurodegenerative afflictions like Huntington’s and Parkinson’s diseases, as well as, the aging process also suggest similar dynamic patterns.

Under “normal” conditions, scale-free invariant patterns can be found in the walking patterns of human beings. In the case of gait dynamics, it is the duration of the gait cycle or “stride interval” which is the unit of analysis for scientists who are studying neuronal control mechanisms for locomotion.[114] The “normal” stride pattern, like the healthy human heartbeat observed with a stethoscope, might *appear* more or less predictable and regular to an observer. But this is seldom the case. One question which researchers like Chung-Hang Peng have considered is whether or not a healthy human gait has a fractal pattern. The answer appears to be “yes.”

The various kinds of observable gaits speak volumes. Consider, for example, a person with a healthy gait to an individual with Huntington’s disease. For healthy individuals, the variation in stride intervals is relatively imperceptible and is invariant over variously maintained walking speeds where the stride appears more or less constant.[115] Peng's research has also shown that long term correlations exist where the distribution of stride intervals fit power laws, thereby suggesting that a healthy gait does have a fractal quality to it. Huntington's disease, on the other hand, manifests itself in the form of very different gait patterns.

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[113] John G. Milton, "Epilepsy: Multistability in a Dynamic Disease," in *Self-Organized Biological Dynamics and Non-Linear Control: Toward Understanding Complexity, Chaos and Emergent Function in Living Systems*, ed. Jan Walleczek (Cambridge, England: Cambridge University Press, 2000), 374.

[114] Chung-Kang Peng, Jeffrey M. Hausdorff, and Ary L. Goldberger, "Fractal Mechanisms in Neuronal Control: Human Heartbeat and Gait Dynamics in Health and Disease," Ibid. (Cambridge), 66.

Whereas fluctuations in the gait stride duration show fractal patterns and long-term correlations in healthy individuals, the stride interval correlations for a person with Huntington's disease are altered.[116] More specifically, the stride intervals are less correlated with previous and subsequent stride intervals and are more random in nature. As such, a person with Huntington's disease appears to walk with a kind of uncontrolled dance-like movement. Moreover, it has been noted that the fluctuations in the stride intervals, as represented in time-series data, between individuals with and without Huntington's disease bear a certain resemblance to the difference between young, healthy subjects and elderly individuals.[117]

It would almost seem like an obvious point of fact: human beings get "older" and, in general, "wear down." Aging, of course, tends to bring with it a dampening of variability across various fractal mechanisms in the human body. Similarly, diseases like epilepsy and the neurodegenerative disorders known as Parkinson's disease and Huntington's disease show signs of increased randomness and a reduction of correlation in stride intervals.[118]

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[115] Ibid., 83, 86.

[116] Jeffey M. Hausdorff et al., "Altered Fractal Dynamics of Gait: Reduced Stride-Interval Correlations with Aging and Huntington's Disease," *Journal of Applied Physiology* 82 (1997): 262.

[117] Ibid.: 265.

[118] Chung-Kang Peng, Jeffrey M. Hausdorff, and Ary L. Goldberger, "Fractal Mechanisms in Neuronal Control: Human Heartbeat and Gait Dynamics in Health and Disease," in *Self-Organized Biological Dynamics and Non-Linear Control: Toward Understanding Complexity, Chaos and Emergent Function in Living Systems*, ed. Jan Walleczek (Cambridge: Cambridge University Press, 2000), 90.

There are, however, significant differences across these different gait behaviours, with the magnitude of changes varying according to the conditions of an individual.[119] These particular patterns are adding useful information to the specificity of dynamical measures.

How would one recognize variability of a fractal nature in a social setting aside from the notion of diversity? To address this question, I turn to the notion of social organizations to explore the place and importance for diversity for this scale of organization and its health.

The Heart of Healthy Organizations

It would seem apparent that certain pathologies arise under particular conditions that might be described as "unhealthy." This view of physiological health might be useful for thinking about the sorts of conditions for "healthy" organizations of different kinds. Indeed, the notion of "diversity" within social systems is a common enough one discussed at this "level," however, the term sometimes gets lost in discourses and discussions about social systems or organizations and oftentimes reduced to concepts of ethnicity, language, sex, ability and so on. Questions about diversity certainly are examples of variability, but there is much more to consider under this concept. It would be useful, therefore, to take note of why variability is important for our understanding of systems across many scales of organization. Variability, as suggested by various scales of spatial and temporal organization, would seem to be important to the "health" of many other scales of organization, including the social.

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[119] J. M. Hausdorff et al., "Gait Variability and Basal Ganglia Disorders: Stride-to-Stride Variations of Gait Cycle Timing in Parkinson's and Huntington's Disease," *Movement Disorder* 13 (1998).

But why, in general, is variability important? Aside from the argument being made here that variability is important for "health," it plays an important role in creating even greater variability capable of propagating even larger macroscopic order. As Kauffman writes:

> *An increasing diversity of broken symmetries in the universe creates the diversity of structures and processes that can constitute and identify ramified and ramifying sources of energy, detect those sources of energy, create devices and processes that couple to those sources of energy, and generate yet more diversity that propagates macroscopic order even further.*[120]

Variability, therefore, is what keeps the world all a-buzz in a kind of mysterious on-going self-generativity. Diversity begets diversity and is a driving force for continued growth, innovation, creativity and novelty–for complexity.[121] In the context of health, then, the presence of diversity allows for an organization to "fit in" with the constantly changing world, that is, the changing environment and the organization itself.

The comparative dynamics of the heart and the human gait, shown in the previous section, open up a notion of health marked by different sets of dynamical patterns described here as "unhealthy" and "healthy." Highly irregular variable fluctuations (of a fractal nature) are suggestive of a healthy organization, and stable, predictable, periodic tendencies are the mark of unhealthy organizations. While numerous examples might exist where there is an implicit sense of unhealthy or healthy comparative dynamics, this awareness is something that will require some time and continued effort to help many to understand the nature of such phenomena. For this reason, an awareness of comparative dynamics needs to be developed, and with that a sense for how one might pragmatically use this notion of comparative dynamics to structure healthy learning organizations.

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[120] Kauffman, *Investigations*, 114.

[121] Stuart A. Kauffman, *At Home in the Universe: The Search for Laws of Self-Organization and Complexity* (New York: Oxford University Press, 1995), 296-97.

Admittedly, I have been influenced by discussions of "health" in a rather specific way and largely through my work outside of academia and in a health and healthcare oriented setting. Conversations with others on issues relevant to biological and physiological health have strongly shaped a much larger view of health. This extended view of health was, in fact, a central topic for discussion with my past work with others, raising for me the notion about healthy organizations, in general, and social and cultural organizations, in particular. Schools and classrooms naturally seem to fit in with this obsession I've taken up, although my work over the past couple of years has been exclusively "outside" of all the usually-taken-for-granted structures of formal schooling and schooled experiences. Nevertheless, I believe there is plenty that can be learned from my experiences that can be considered in light of formal education, schools, schooled experienced, learning and teaching.

Before considering and offering up a view of social organizations and educational settings framed and described according to the notion of comparative dynamics and "healthiness," some consideration will be given to the notions of "surprise" and "unexpectedness." These notions have been taken up on a variety of different fronts, including the disciplines of psychology, philosophy and cognitive science. Moreover, paradigmatic complexity can be thrown in with the mix, having been referred to as the science of surprise.[122] Briefly put, surprise–an expression of unexpectedness–has a great deal to say about what it means to be human, cognition, and our relations to the world. The expression of surprise, moreover, is also connected with this notion of comparative dynamics that has been introduced in this chapter. This will be explored shortly. In the next chapter, the notions of surprise and unexpectedness are raised with some attention to the lived-experience of surprise and some neurophenomenological considerations. The chapter will end with a complexity-inspired framing of the notion and concept of surprise.

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[122] J. L. Casti, *Complexification: Explaining a Paradoxical World through the Science of Surprise* (New York: HarperCollins, 1994).

Chapter 4

SURPRISE AND UNEXPECTEDNESS

Experiences of Novelty in Learning

> *The importance of nonsense hardly can be overstated. The more clearly we experience something as "nonsense," the more clearly we are experiencing the boundaries of our own self-imposed cognitive structures. "Nonsense" is that which does not fit into the prearranged patterns which we have superimposed on reality. There is no such thing as "nonsense" apart from a judgmental intellect which calls it that.*[123]

Novelty. Unexpectedness. Surprise. What do these words mean? The terms appear in a variety of different literatures and discourses–the complexity sciences, psychology, phenomenology and philosophy, to name some–except their use is far from unified. In fact, these notions do address a wide range of human experience in very different ways. For this reason, some attention should be given to these differences, in part, to uncover some of the original intentions that may have been implied or intended when they were first invoked by our ancestors.

Although it is my intention to discuss this notion of "surprise" from a complexity-inspired point of view (within the broader studies of the complexity sciences, novelty, surprise and unexpectedness are used almost interchangeably), the traditions of psychology, cognitive science, phenomenology and philosophy have also played a role in our understanding of the phenomenon known as surprise. It is not my aim here to be exhaustive in a survey of how surprise is understood within these traditions.

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[123] Gary Zukav, *The Dancing Wu Li Masters: An Overview of the New Physics* (New York: Morrow, 1979), 140.

Rather, in browsing through these fields, I am looking for some opportunities to create or re-invent a more complexified understanding of surprise. The role of surprise, as we will see, has some very different affects on an organization when framed by comparative dynamics.

On Expectations, Certainty and Anticipations

Human beings frequently expect to encounter certain features of the world that are stable, knowable and predictable, that is, those "things" that can be understood and explained or described with some certainty as being "there" in the world. We sometimes forget that frequently we are expressing a tacit expectation that certain things are to be a certain way. It would follow, then, that worldly phenomenon can be known in "no uncertain terms," and thus the phenomenon itself is or must be a fundamental part of "reality" and absolutely knowable. There are no "hidden" variables from which a little more "digging" could bring to the surface the essences of worldly phenomena.

Now consider some event in history that you remember happening that was unexpected. One could never say that one would have expected such a thing to happen. In fact, it is most likely that one would have said, "What just happened?" or "What was that?" and afterwards, "How *could* that have happened?" Unexpected happenings unfold suddenly–sometimes right before our eyes–and should raise some questions about our own sense of certainty and expectation.

An "expectation" literally is a "looking out" (*ex-* + *spectare*)–even a looking out *for something*. While its etymology will not necessarily retrieve its essence, which once may have resonated with its lived meaning, the origins of its meaning, however, may still "put us in touch with an original form of life."[124] In this manner, an expectation is something that connects us with the spectacles of the life-world, with the events and happenings of a world that unfold with us in some complex, extra-ordinary choreography. To "look out" is to bring forth some object-in-the-world from an undifferentiated world–that is, to draw out (as when one draws a boundary with a pencil or crayon on a piece of paper or stick in the sand) from the background of human experience something distinct from that background. The mood of expectation, that is, this *looking out for something*, suggests that we are prepared for or planned to look at something in particular, some object-in-the-world. But what about when we are *not* looking out for something–when we are not expecting something? Is this different from the experience of "unexpectedness?" Quite possibly.

Views of Unexpectedness and Unexpected Events

I've never ever taken the time to go to flea markets or to yard sales. I can imagine, however, what it might mean to stumble upon the "unexpected find." Sometimes the stumbling is literal, and sometimes it is not. One is not necessarily looking for anything in particular, but then all of a sudden ... there it is! My friend and an incredible bibliophile, Toby, speaks every now and then of such occasions. Most of the time there is very little that catches his attention in the many seas of books that sweep before him, but to hear him speak of the occasional gem makes it abundantly clear that the literary find is quite unexpected.

I would describe my "discovery" of a significant topic to my work and emerging interests in a similar fashion to Toby's unexpected literary finds.

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[124] Max van Manen, *Researching Lived Experience: Human Science for an Action Sensitive Pedagogy* (Albany, NY: State University of New York Press, 1990), 58-59.

Clearly, in my mind anyway, the event was quite remarkable and unexpected. I was sitting at home one evening at my desk, reading through various unrelated articles by the light of a single lamp focused on the papers before me. For some reason, I had picked up a copy of an article by Brenda Zimmerman only because it had the term "complexity science" in the title.[125] I flipped through it–I'm a selective reader at times–and found two paragraphs buried in the middle of the piece. I was not trying to solve a problem so it was not some "Aha!" moment, but it had that feel of "That's it!" Suddenly I had a pretty good sense of what I wanted to spend my time thinking about–perhaps even for my dissertation. I would say that this moment was rather unexpected–the find being my on-going interest with the experience of surprise.[126]

How do human beings experience unexpected events? It does depend upon to whom one asks the question. As was suggested earlier, this chapter aims to present a complexified view of surprise; however, some thoughts on the topic from psychology, neuroscience and phenomenology will be explored.

Views from Psychology

It is sometimes presumed that causality in the physical world suggests an absolute given in the relation between a specific causal event and an equally specific outcome. In other words, every outcome must have a specific set of *a priori* conditions; however, not everything in the life sciences obeys the principle of absolutely specifiable causes.[127] Cognitively speaking, however, such relations are not always the rule. Instances such as a change in thought and its corresponding neuronal activity denote a relation between an event and the expectations of an individual. The power of the inconsistency between an event and a person's expectations or beliefs is described in the field of psychology as a "discrepant event."

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[125] Brenda Zimmerman and Bryan Hayday, "A Board's Journey into Complexity Science: Lessons from (and for) Staff and Board Members," *Group Decision and Negotiation* 8 (1999).

[126] In some ways, I have Brenda Zimmerman to thank for this "connection" that I made on that cold evening in March shortly after I arrived in Edmonton to continue with my studies. Just as interesting and unexpected, later that year at a conference in Toronto, I met Brenda. I had not anticipated meeting her and I had in fact "forgotten" her. "Something" happened in the middle of a presentation she was giving, and all of a sudden I realized I had "met" this woman already. I was quite surprised.

The human brain is deeply sensitive to change, mediated by various complex neuronal assemblies. As such, understanding change, difference and discrepant events requires knowing "the mind of the agent in order to predict the psychological consequences of an infrequent event."[128] To be clear, it is not so much the event as might be observed by others or recorded by some camera, but the relation between an event and a person's understanding of that event or expectations for such an event. In addition, the response to novelty or an unexpected event is dependent upon a number of different factors, including gender, past experiences, the context and perceptual biases.[129]

Psychological phenomena and biological phenomena (as with the brain, for instance) should not be viewed as one and the same. Certain discoveries have suggested that patterns of neuronal assembly activity correlate with particular psychological patterns. Nevertheless, they are quite different phenomena which require different perspectives shaped by different vocabularies and framings. Psychological phenomena are emergent phenomena, analogous to other happenings that arise from collective inter-dependent activity.

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[127] Jerome Kagan, *Surprise, Uncertainty, and Mental Structures* (Cambridge, MA: Harvard University Press, 2002), 9.

[128] Ibid., 10.

[129] Ibid., 13.

"Discrepant events" is a term fitting for psychological events, but is not particularly well-suited for neuroscience perspective.

Views from Neuroscience

To many neuroscientists, the brain represents the "organ of the mind."[130] It is the wrinkly, gelatinous 3-pound mass of tissue that has sometimes been referred to as the "seat of reason" or the "soul in the machine" nestled within our heads. Certainly, it is more than a mere mass of jelly: on some level it is a large connection of massively entangled, basic, functional units called neurons or nerve cells. In fact, the brain is, as John Ratey writes:

> *An overgrown jungle of 100 billion nerve cells, or neurons, which begin as round cell bodies that grow processes called axons and dendrites. Each nerve cell has one axon and as many as 100,000 dendrites. Dendrites are the main way by which neurons get information (learn); and axons are the main way by which neurons pass on information to (teach) other neurons. The neuron and its thousands of neighbors send out roots and branches–the axons and dendrites–in all directions, which intertwine to form an interconnected tangle of 100 trillion constantly changing connections.*[131]

Although it is no longer held to be the case, the brain was once viewed as being fixed after a certain period of development, where neurons could die, but they did not regenerate nor re-organize themselves.[132] Thanks to technologies that are available to the modern medical establishment, we now know that the brain is a very different kind of organization. Indeed, the brain is often taken as and suggested to be the most complex organization known to humankind. It is a frequent candidate for discussion about complex phenomena and fittingly described by many complexity science notions.

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[130] James H. Austin, *Zen and the Brain: Toward an Understanding of Meditation and Consciousness* (Cambridge, MA: MIT Press, 1999).

[131] John J. Ratey and Albert M. Galaburda, *A User's Guide to the Brain: Perception, Attention, and the Four Theaters of the Brain* (New York: Pantheon Books, 2001), 19-20.

[132] Ibid., 20.

Studies of the brain are numerous although they are not coherent and congruous in nature. Similarly, studies of the role of the brain in the experience of surprise are no different. Nevertheless, there are certain phenomena that are frequently addressed in the context of surprise, unexpectedness and anticipation: these are P300 potential wave forms or P3 waves which are positive waveforms which arrive 300 milliseconds *after* some outside stimulus, and are found in the pre-frontal cortex of the brain. Stimuli requiring more time than this are believed to be going through various processes of filtering to make sense of the world.[133] Moreover, for individuals who experience some sort of brain damage over the frontal area of the brain, P300 potentials become lost, and experiences of novelty and flashes of insight or wisdom become much rarer events.[134] Therefore, rather than allowing for highly creative acts, more stereotyped and less adaptable behaviours are observed. Surprise, after all, does seem to signal a moment when adaptation might be necessary for "going forward."

This sense of being able to "move forward" is a neurologized notion attributed to the frontal lobe of the brain. Surprise seems to happen when some anticipatory functioning or "foresight" of the frontal lobe "meets up with" an altogether different experience. As such, the frontal lobe plays a multi-functional role in generating goals that are desired and in considering the social appropriateness of such actions, while discerning which action would be best suited for future actions.[135]

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[133] Austin, *Zen and the Brain*, 285.

[134] Ibid., 257.

In the case of an uncommon, but, perhaps, otherwise anticipated event, a very different electrical potential in another area of the brain, that is, in the parietal lobes, would be evoked. The difference between the experience of novel stimuli as shown through the waveforms in the frontal lobe and parietal lobes is manifest in different temporal dynamics and "neurologized" questions that those areas might "ask."

In the case of the frontal lobe, the overall brainwave pattern is slower in comparison to the much quicker patterns of the parietal lobes. Put differently, the dynamic pattern of the brainwave potential in the frontal lobe might be likened to a slow climb up a hill. Metaphorically speaking, after a tremendous amount of time (relatively speaking, of course) of climbing up the hill–large amounts of "information" are filtered and interpreted from the experience, the question "What-was-that?" remains unanswered. Thus, at the top of the metaphorical hill, one might speculate that the brain asks, "Now what?" and a sense of uncertainty may present itself.

On the other hand, the parietal lobe is much more active as it is continually "looking out" for particular anticipated stimuli or experiences. In this manner, when the parietal lobes are more active, they may be poised to "ask" the question, "Where-is-it?" And, upon finding the anticipated experience or stimuli, there is this sense of "There it is!"

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[135] Ibid., 149.

These neurologized questions might not seem too strange. After all, they are common aspects of the human experience of surprise, that is, the phenomenological or lived-experience of surprise.

Views from Lived-Experience and Phenomenology

In this section, a view of "unexpectedness" is framed by a phenomenological sensibility. "Unexpectedness" as a lived human experience is not some phenomenon limited to one particular kind of experience. Consider my experience of "finding" what I wanted to study or Toby's unexpected literary finds. What is it that one recognizes in a moment of unexpectedness? When one is shocked to hear news about the death of someone that one knows well, is that said to be an experience of "unexpectedness?" Is my work colleague who appears startled whenever I approach her with a question, who appears so completely unaware of my presence, experiencing unexpectedness? What about other experiences? Would it be like having guests suddenly show up at your door unannounced? What about a surprise birthday party? Is "unexpectedness" any of these things: what is the lived experience of unexpectedness?

In the realm of human experience, one might say that we are seldom surprised. It is taken to be a rare event–something special. It is not everyday, for example, that Toby has this kind of expectedness in a second-hand book sale or yard sales. Why do we not experience surprise in every moment of life? The unexpected is some unanticipated event. That is, it comes unannounced, and, just as suddenly, it disappears. It is unforeseen. One can never "see it coming."

In this way, surprise has this way of sneaking up on us. Interestingly, the etymology of the word surprise has something insightful to say to us about this notion of "sneaking up on." As van Manen writes, "Being attentive to the etymological origins of words sometimes put us in touch with the original form of life where the term still had living ties to the lived experiences from which they originally sprang."[136] Thus, the word surprise is closely related to such notions as "a sudden unexpected attack," "to come upon unexpectedly," "to take unawares," "the feeling or emotion excited by something unexpected, or for which one is unprepared" or something "akin to astonishment and wonder, caused by an unexpected occurrence or circumstance." There is a sense of being "overtaken" (*sur-* + *prendre*).

Etymologically, then, the idea of being surprised is, as the Oxford English Dictionary suggests, about being "taken over" or "attacked" all of a sudden. It is an unexpected event or happening for which we might be unprepared. Some people may also believe that surprise can happen by design. That is, surprises can be deliberately planned events to catch *someone else* "off guard." Certain aspects of the planned surprise must be kept away from the other. In other words, the surprise must remain hidden or invisible to the other. But is an unexpected event simply there before us waiting for us to trip over it–most likely, in some accidental manner?

Sometimes it might appear to us that surprises are hidden from us, however, the unexpected need not be hidden at all. In fact, the unexpected happening may be there in front of us all the time. But why is it that we might not even see it? The difference may be a distinction between seeing and looking. In looking, we are paying attention, and there is an act of intentionality. When we are merely seeing, the world fades into a background of over-familiarity.

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[136] van Manen, *Researching Lived Experience*, 58.

Our expectations, therefore, suggest a particular way of orienting ourselves in and to the world: all-at-once we orient ourselves *to* something while we orient ourselves *for* something. In this manner, then, expectations are a *perspective* on life. It is a bi-directional view of and on the world that is marked by *intentionality*. We are simultaneously drawn to and attach ourselves to the world to become more fully embedded in it as we become the world.[137] As Heidegger describes the task of phenomenology–it is giving an account of "the being of the intentional."

Unlike unexpected events, events that are expected or are not expected suggest a particular relation with and to the world. That is, there is a different lived-relationality with events involving expectations of some kind that do not belong to the fundamental structure of unexpectedness. This relation has significance for us where the world appears as a stable objectively-tethered world. This suggests a particular mode or way of knowing the world. When it is assumed that the world is some objective given, a one-to-one logical correspondence between the world and our perception of the world establishes what we know and what can be known. This suggests that we can know the world clearly if only we pay attention to what is out there. However, as Merleau-Ponty writes, "no real landscape is in itself unclear. It is so only for us."[138] The world is, rather, a space of indeterminacy where the expressive quality of unexpectedness arises within a world of logical significance for oneself and social collectives. That is, the world is essentially and "unlabelled"

Even so, many people's experiences suggest a certain sense of familiarity, of being familiar with the world. In this manner, one might say that one's experience of the world is linked to a comfortable practice of being involved in the world. Unexpected events, then, can catch us "off guard" when our experiences of the world around us cease to be familiar. The unexpected happening is not an everyday occurrence, and so that which we do notice is what is unfamiliar to us. Why else would one ask, "What was *that*?"

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[137] Ibid., 5.

[138] Merleau-Ponty, *Phenomenology of Perception*, 6.

More importantly, the suddenness of the unexpected event announces a particular lived temporality. It is more than some imperceptibly small moment in time. "Suddenness" has a certain qualitatively experienced temporality. Suddenness is different from the lived temporality of anticipation–the modality of expectation. Whereas expectations involve looking toward the future, the suddenness of unexpectedness involves a mode of being that is situated in the present moment.

To be sure, it could probably be said that people have different views of what a surprise is, and how and why it happens. Moreover, in the context of organizations and how they are conceived, the notion of surprise seems to carry different sensibilities depending upon the metaphorical view of the organization. The following section examines some different metaphors, their relation to "structure" and some possible implications for particular senses of the notions of "surprise" and "unexpectedness" when viewed against different metaphorical frames of organizations.

Unexpectedness and Organizations: Metaphorical Views

Organizations are frequently described in a variety of ways. In fact, a number of different metaphors are often presented as particular views of organizations, in general, and of educational learning organizations, more specifically: organizations are sometimes described as machines, brains, organisms, and as cultural and political bodies: depending upon the particular metaphorical view or orientation to the organization, unique ways of seeing, understanding and shaping those organizations emerge. Moreover, as organizational scholar, Gareth Morgan notes, these views create a range of complementary and conflicting views. These metaphors will not be explored here, as they have been sufficiently explored elsewhere in so many other contexts; however, two metaphorical frames of learning and learning organizations will be explored with the intent of examining how the notion of surprise might be understood within each frame. To be clear, the two metaphors that will be taken up here are the familiar notions of learning and organizations as machine and biological structure. Each metaphorical image has its own strengths and limitations with different implications for thinking about surprise. First, however, some brief remarks will be made on the place and use of metaphor.

Structures of Metaphor

Albeit a simplification of a complex concept, metaphors invite us to find or see similarities while ignoring differences that might present themselves to us between two different objects, phenomena or events. Certainly, powerful insights can be gained from such comparisons, however, there is also the risk of distorting what we aim to see or understand, and thus the metaphorical framing becomes a way of not seeing what might really be there.[139] The construction of metaphor–whether poetic or ordinary and everyday–plays a huge role in "knowledge production" as metaphors influence the myriad of ways in which we conceptualize what we know and how we know or think about life and our experiences in practically every waking moment of our lives.

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[139] Gareth Morgan, *Images of Organization*, 2nd ed. (Thousand Oaks, CA: Sage Publications, 1997), 5.

Complex metaphors are composed oftentimes of primary metaphors, which are grounded in experiential domains of sensorimotor actions.[140] From our earliest years as children, these experiences (such as the subjective experience of quantity expressed in terms of the experience of verticality, or the understanding of an idea in terms of grasping an object) automatically and unconsciously shape our minds in a conflationary manner in the form of a cross-domain mapping. That is, connections are made between two co-active domains: a subjective experience or judgment and a sensorimotor experience. Thus, primary metaphor becomes embodied knowledge where knowing cannot be separated from acting and who we are as human beings. Or, as Chilean biologists Maturana and Varela write: "All doing is knowing, and all knowing is doing."[141] In this manner, we see that cognition is inseparable from perception: it is fundamental to action. Therefore, for most human beings, primary metaphors are a human inevitability as human beings constantly move about in their own worlds.

Because of the kind of body and brain that we have and the world we live in, human beings create and bring forth numerous primary metaphors that structure subjective experience. Therefore, the world as human beings understand it, and more specifically, its patterns of organization (as in human organizations and social systems, for example) are sometimes described in terms of very specific metaphors. We invent or otherwise co-opt certain metaphors to describe, understand or create different social structures. For instance, the metaphor of "grasping" an idea, a common example of how we might frame the notions of knowing and understanding as being able to

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[140] George Lakoff and Mark Johnson, *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought* (New York: Basic Books, 1999), 45.

[141] Humberto R. Maturana and Francisco J. Varela, *The Tree of Knowledge: The Biological Roots of Human Understanding* (Boston, MA: Shambhala, 1992), 26.

"hold" an idea, "see" it, and "manipulate" it, is a prevalent example of how a particular metaphor structures how one might describe, understand and create particular "views" of the world through one's particular embodiment. That is, through our physical engagements with the material world, as when we touch, grab and hold on to objects, the notion of being able to interact with an idea in the same fashion emerges through one's subjective experiences.

Metaphors of Structure

When it comes to the management of organizations and thinking about learning, a number of different metaphors present themselves. Most common are those metaphors which, on one hand, stand in line with the notions of "command-and-control" structures, clockwork structures, the mechanization and streamlining of departments and hierarchies, and so on: on the other hand, there are a collection of metaphors that might be described as organic, holistic or ecological. Thus, the notions and images of webs, networks, swarms and schools of fish are common images. As noted in the previous section, the choice of metaphor shows how our actions can be profoundly shaped to act in particular ways. That is, a very different way of engagement can be enacted in social settings whether the guiding metaphor is shaped by more "command-and-control" structures or "organic" ones.

In either case, these two notions of "structure" reflect two prominent ways in which it has historically been taken up. On one hand, it does imply a rigid form, as with the "structure of a building" where such "structures' are to be anticipated and fixed artifacts or edifices. In education, the notion is oftentimes expressed, for example, in the form of a "lesson plan" or teaching or learning. The following example shows rather dramatically how such a conceptualization has found its way into the language and discourse of teaching and learning:

> *Scaffolds allow students a framework on which they can build their own knowledge and provide help in organizing their thinking, with the goal of gradually removing the scaffolding and allowing full ownership of the constructed knowledge. ...[E]ven when the proper balance is struck by creating an appropriate scaffolding, there is the danger that it might become a permanent fixture.*[142]

Contrary to the architectural construction of "structure," the more popular meaning has and continues to share a radically different sense that is more in line with a biologist's or ecologist's use of the term. That is, the more commonly held beliefs about premeditated, permanent and deliberate artifacts of society have taken the place of the more contingent, evolving projects of learning and evolutionary processes. Taken together, we see that the notion of "structure" is simultaneously understood as caused *and* accidental, stable *and* emergent, autonomous *and* contingent.[143] Thus, the two notions nicely point out how contradictory and contrasting in nature two meanings of a single metaphor can be.

These two metaphorical structures hold some relevance to the emerging connections in this work on comparative dynamics and healthy organization. In the previous chapter, I introduced the notion of comparative dynamics which pointed to the possibility for different metastable patterns to emerge through varying dynamical interactions of a given organization. These patterns, described in terms of stable and predictable patterns versus more dynamic and unpredictable ones, descriptively correlate with the possibilities for action and becoming that machines and living systems can bring forth. Again, it is not so much that my heart, my immune system, my entire body, or my social network and the entire ecology in which I am embedded could be–or be *like*–a machine, but rather that the nature of the interactions and connections that create these various kinds of organization and experiences are expressions of disconnectedness and limited and limiting possibilities for growth, change and adaptation. In this manner, it is said that such organizations are unhealthy: the converse, then, is that a highly fractally interconnected and interactive organization is a healthy one. Taken together, the notions of "health" and "healthy organization," therefore, have been extended metaphorically to encompass something much larger than the well-being of humans that goes far beyond the usual Western sense of wellness that treats illness and disease in terms of removing "parts" that do not work in the well-oiled machine that is the human body. Put differently, a metaphor of health is being introduced here to describe the organizations that fall under the notion of comparative dynamics.

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[142] S. R. Williams and J. A. Baxter, "Dilemma of Discourse-Oriented Teaching in One Middle School Mathematics Classroom," *The Elementary School Journal* 97, no. 1 (1996): 23, emphasis add.

[143] Davis, Sumara, and Luce-Kapler, *Engaging Minds*.

In the same spirit as Gareth Morgan's work on metaphors and organizations, the remaining sections of this chapter will examine these two metaphorical sensibilities in the context of schools and learning. Depending upon what "view" may be taken, that is, which metaphorical frame, different interpretations of "surprise" emerge. To be clear, these are conceptual interpretations of learning, learning organizations and surprise, and are not necessarily phenomenological in nature. Its phenomenological qualities, however, will prove useful in a discussion on the form of a "complex" model for surprise.

Depending upon the particular view that a person or organization may have, surprises and surprising moments can be thought of and addressed in a variety of ways. In fact, surprises and surprising, unexpected events happen all the time. On one hand, surprise can be something that is not desired, something suppressed or controlled for. Or, it can be something that is embraced, sought out, encouraged or even necessary. Just as a particular view of an organization or learning might shape a particular view of surprise, the conceptual view of surprise may also have some profound effects upon an organization. Those effects, however, are quite different depending upon the "nature" of the organization.

Mechanical Structures and Thinking

The emergence of different technologies throughout history has created a variety of tools that have proven to be more than merely useful in the lives of human beings. Culturally speaking, the West in modern times has commonly viewed technology as the creation and application of devices, tools and measuring instruments. This has not always been the case. Indeed, etymologically, technology derives from ancient Greek where it suggests a means of bringing forth a world of significance rather than manufacturing one. Whereas a common understanding of technology is about mechanical devices, its original meaning was more toward extending our human capabilities. Thus, human beings have evolved to include language, linguistic technologies like scripts and printing presses, electronic forms of communication, the internet, e-mail, PDAs and wireless cell phones. In these cases, technology has helped us to extend ourselves, influencing the shape of our individual and collective identities of self-making.[144]

Technology and the use of machines to do work have radically changed how human beings function in the work place, at home, and at play. In many ways, technological advancements have left their marks upon our imagination, thoughts and feelings.[145] As such, we should wonder very little how and why scientists, philosophers, psychologists, health care practitioners, educational curriculum developers and corporate managers, to name but a few vocations, have described the world, our place in it, theories of cognition and human behavioral patterns in terms of mechanical frames. Human beings have learned and adopted quite well the image of the machine as a way of structuring their views of themselves and their actions in the world. Many modern organizations create this perception for those whose lives are enmeshed within the daily practices of these organizations.

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[144] Ibid., 170-71.

Although overly simplistic, the current image of schools is sometimes described in terms of a machine or factory. Teachers and students show up to "conduct their business" at carefully prescribed times. Some of my fellow teachers, as well as myself, have been known to sign in at the main office. Student attendance is taken. The clock governs the actions of teachers and students with predetermined activities performed by all, including breaks for recess or lunch. Bells indicate changes in activity. Work is sometimes described as mechanical and repetitive, and the general feel is sometimes described as that of factory work. Performance is monitored on many levels. Everyone has a place like a cog in the larger machine known as the school.

The notion of a bureaucracy is often conflated with an organization that functions or is otherwise perceived in the image of a machine. But no organization functions as a machine, let alone *like* a machine. Many aspects of how organizations work do indeed have some form of mechanization so that they might function in some orderly fashion. As a result, a literalization of the machine metaphor begins to take shape where as a consequence the way we think about the organization becomes the way we expect the organization to function. Thus, bureaucracies are expected to perform in some reliable, efficient and predictable manner.

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[145] Morgan, *Images of Organization*, 12.

This is not to say that mechanized organizations are bad. There are times when an organization should operate in this mechanical mode, particularly when efficiency is desired for effective operation. On the other hand, a mechanized organization can be an absolutely devastating place for the worker as well as those people for whom the organization is meant to serve or at least interact with.

Implications for a Mechanical Organization

Mechanical organizations–organized structures that may be actual machines or function *like* machines–have particular qualities about them. Machines can be thought of in terms of being the sum of their parts, parts that interact with one another in predictable ways to perform some task–sometimes a task that can be articulated before it is carried out to arrive at some predetermined set of outcomes. Like machines, organizations through the dynamics that create them can also create a perception of a similarly rigid structure that must operate with predictability, certainty and no unexpected events. For people who live and work in organizations where there is a sense of a need to control or eliminate the unexpected, such organizations are sometimes described or referred to as functioning as if they were machines.

To be sure, not everyone experiences going to school or working in one in quite the same way. One of the reasons why I embarked upon doctoral studies in the first place was to pause to think about why my own experiences as a student and teacher were not so stellar or positive. I can recall my own high school math teacher forewarning us about what was to come in university. "You're just a number to them," he would say. Although this was probably said at a time when he felt we needed to work harder, what I think he intended to convey was this sense that going to school and learning was all about quietly and independently working hard in a place where relations were apparently not all that important to people like some administrators and faculty members. We were nothing more than cogs in a machine without feelings.

Happily, I attended a relatively small university and department where faculty knew their students. That much is hardly disputable in terms of my own experiences. It was not an uncommon experience for me to chat with my peers and departmental faculty about different matters in the hallways or during the daily mid-afternoon tea time. Still, classrooms generally were quiet places where faculty lectured, and on occasion took up questions. This is not to say that my mathematics classes were held in large auditoriums. On the contrary. Calculus classes were seldom over 25 people, and by second year, class numbers were on the order of a dozen or fewer people. And while upper-level classes had a little more interaction, they were not so conversational in nature. Questions were more for clarification rather than inquiry and exploration.

Even if my experiences at university were more towards the way that my high school teacher had described, I think that it would be inappropriate to describe the university as a machine or an uncaring educational institution. Nevertheless, the *experience* of feeling disconnected is not something to be ignored, and I am sure that some of classmates (who were not mathematics majors) found that their experience of sitting in our mathematics classes simply made no sense to them. Perhaps this notion of "making sense" has some metaphorical significance with sensory perception. So if mathematics didn't make sense to my colleagues, perhaps they would similarly describe it as a disconnection. As far as my own experiences go, I would probably say that I experienced a similar disconnection as mathematics was largely a matter of applying a few rules to objects. It didn't have to "make sense" to me as long as I just applied the rules when I was supposed. Any kind of relations or connections seemed absent for me, that is, until I gave some consideration to the historical aspects of mathematics and people who did mathematics.

I frequently hear from people, just in passing, that they hated mathematics or did not do it well. Classrooms felt "cold," "rigid," and not particularly "caring" places. Like other "captive audiences," these experiences of isolation (from ideas, one's peers and teachers, and sometimes a larger institution) seem to suggest something like being a part in a machine with greatly dampened interactions with other parts.

Organizations that remain in a state close to equilibrium do not have the same capacity to adapt to change or transform themselves easily or readily. One might say that such organizations are "shackled."[146] Like a prisoner handcuffed or confined to a jail or holding cell, the shackled individual or organization is hopelessly stuck within the narrowest of possibilities. And, like the prisoner in a prison, where neither has the capacity to look at life in any other way except through the confines of carefully guarded organizational boundaries, lifelessness and dreariness are the order of the day.

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[146] Jeffrey Goldstein, *The Unshackled Organization: Facing the Challenge of Unpredictability through Spontaneous Reorganization* (Portland, OR: Productivity Press, 1994).

People who work or live in some way in this kind of organization, a "shackled organization," not only feel they can act in the narrowest of ways, but they are often told to act in particular ways: Do this. Follow your job. Mind your own business. And, so on. Sadly, I am sure that many people can look back upon some or perhaps many school experiences where the same kind of organizational experience presented itself. Math class is for doing mathematics, but only those lessons that the teacher tells you to do, and almost always independently. I shudder at the thought of some of my own past experiences teaching mathematics where I stand over a student who is looking out a window and ask, "What are you doing?" only to be met with the response, "Thinking." I guess we're not supposed to think in math class. I wonder where I got this from? Clearly, the only way that learning could happen was if it were almost dead silent and under the control of the teacher where everything had to be known in advance and few surprises would happen! Have I and others lost an ability to transform ourselves from our past shackled experiences to something a bit more humane, built on healthy relationships?

So how does one view surprise particularly in light of a machine metaphor? In general, it can be said that being surprised is an experience with a world or features of a world that are out of place. That is, one becomes surprised by a world that defies our expectations for it. The world is supposed to be stable and predictable with a place for everything and everything in its place. And so, for example, schools and classrooms are to be very particular kinds of places. Were my experiences and the experiences of my peers of our math classes supposed to be so disconnected and impersonal? Certainly there are some people who believe that students should sit in the classroom, be quiet and do their work quietly and independently–like my high school mathematics teacher. (For the record, this should not be taken as some kind of dislike for my senior high math teacher. If anything, he was quite influential in terms of my interest in mathematics.) When there is a breakdown in the "natural" world-order, the potential and possibility for one to be surprised occurs. Moreover, such a view often parallels a notion that the world can be controlled and directed in very specific ways. Sometimes, therefore, a person might say that he or she is surprised when some directed wish does not happen as planned.

Unexpectedness and Biological Structures

Some organizations tend to work rather well in stable or protected environments: bureaucracies tend to work well in such contexts, however, other types of organizations work better in other types of surroundings. That is, a "kind of biology" has proven useful for organizational theorists and practitioners. There are many different types of biological images that have come to shape different views of organizations: rhizomes, spider webs and trees, for example. In addition to these, there is the image of the brain.

Brains are not information processing machines.[147] They are not computers in the modern technological sense of a computer. Human brains are not "hard-wired," and yet popular conceptions of the brain as being an information processor persist. The structure and anatomy of the human brain resemble nothing like a computer or telephone switchboard, the television or the data storage and retrieval systems of a library.[148] The human brain is a complex emergent organization.

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[147] Maturana and Varela, *The Tree of Knowledge*, 169, 96.

[148] The brain, as well as the mind, often has been described through a variety of different metaphors. To be clear, the brain has not always been described in terms of computers, for instance, and the way that it functions. Historically, other kinds of metaphors have been used to describe the brain that seem to reflect the knowing of a much greater social collective where the language of cognition

What must be borne in mind again is that the image of an organization as a brain carries with it some useful insights, however, it also provides an incomplete and partial view of an organization. How do human beings view and understand the inner workings of the human brain? It is said that human brains are resilient, self-organizing, adaptive, and plastic.[149] But is it possible for the image of the human brain to be an adequate image for an organization? Can an organization–a school or classroom, for instance–be resilient, self-organizing, adaptive and flexible in the same manner?

There is nothing inherently wrong with the image of organizations as machines. Indeed, it has been and in some sense continues to be a useful way of thinking about and framing the work of some organizations that are information, decision-making and communication systems.[150] Still, it also may not be helpful–let alone accurate–for thinking about learning and learning organizations. The image of a brain as well may hold some useful insights into learning organizations, but it also holds some problematic assertions.

The focus on the brain as an image for the organization, a "learning" organization, falls in line with what many in the learning organization business have been saying about learning and organizational design. With a strong emphasis on decentralized processes, the brain as organizational metaphor offers a striking departure from the traditional views of organizational management. The brain metaphor challenges much about how organizations might function on leadership and control, goal-setting and

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seems to reflect the prevailing technologies of the time. *Cf.*, Davis, Sumara, and Luce-Kapler, *Engaging Minds*, 52.

[149] Camazine, *Self-Organization in Biological Systems*, Jensen, *Self-Organized Criticality*, J. A. Scott Kelso, *Dynamic Patterns: The Self-Organization of Brain and Behavior* (Cambridge, MA: MIT Press, 1995), Maturana and Varela, *The Tree of Knowledge*.

[150] Morgan, *Images of Organization*, 78.

objectives, hierarchical relationships, organizational design and the development and imposition of a system from the "top down."

Although the image of the brain poses a strong image for viewing organizations in that it asks traditional management practices to be more open, there is the problem of self-referentiality. In a crude way, we are brains looking at brains. However, there is no coherent view of the human brain. In fact, researchers know very little about how the brain works. But more importantly, there are the realities of today's organizations vis-à-vis power and control. Tremendously difficult shifts are sometimes needed to move an organization from a command-and-control structure to one where the distribution of power and control allows for the possibility of new, plastic, evolving patterns. Openness and decreased autonomy are needed from upper levels of management in order for the organization to be slightly out of control. In other words, in addition to there being a shift in the thinking about the function of autonomy in the way various parts of the brain function, there must also be a shift in the ways in which power is distributed throughout the organization.

We might now reconsider the question, similar to the one asked in the previous section, about surprise: how might one view surprise aided by the metaphor of a biological entity like the brain? As suggested in another part of this chapter, unexpectedness as a lived experience would appear to be quite different from the idea that something might not be expected. Framing an experience in terms of *not* expecting something suggests that something was expected albeit something quite different. But unexpectedness and surprise arise within a context that appears, phenomenologically speaking, to have nothing to do with expectations. So, what does the experience of surprise framed by the metaphor of a biological entity tell us?

I would offer that the experience of surprise is an indicator of a deep-rooted sense of the familiar that has become so familiar that one no longer needs to be aware of one's own expectations and experiences something surprising when suddenly confronted by something strange or unusual. The experience of surprise, therefore, suggests a particular biological mechanism to drawn one's attention to something that is seemingly "below the radar" of perception, taken-for-granted and not quite right for some (and sometimes unknown) reason. In other words, for biological structures which have a filtering mechanism to cope with the fullness of life, surprises are those markers of something one could never have expected anyway. And, when surprised, one's attention is called to think and act a little differently and adapt to a changing or more complex world. That is, surprises are reminders of not only how strange and complex the world is, but how much stranger and more complex we can possibly perceive it. Surprises, therefore, when framed by a more biological metaphor point to how organizations need to be able to adapt to change rather than working from the point of view that the world should be a particular way no matter what.

Models of Surprise

Early in my studies of complexity and complex systems, I often would find statements in various forms that would allude to some notion of "surprise." What I noticed about these descriptions is that none of them appeared to address the lived-experience of surprise. In other words, what was the structure of this experience that had caught my eye way back when? In addition, I wondered if the experience of surprise could be described differently using complexity-related notions. In a manner of speaking, I wanted to turn complexity back upon itself. As a "science of surprise," it seemed all the more appropriate for me to take some of the ideas I picked up from my studies of complexity and try to apply them to the lived-experience of surprise.

In *Reality Rules*, John Casti remarks: "One of the great challenges to both science and philosophy is to provide a rational account of the uncertainty we perceive in the events of daily life."[151] A number of different "rational accounts" have been proposed, but very little satisfactory progress has been made. In particular, Casti notes that the theoretical frame for understanding "surprising events"–not the lived-experience of surprise–based on classical probability theory has a number of epistemic flaws and deficiencies.[152] In spite of subsequent theories, *e.g.*, fuzzy logic, few improvements have been made. What is clear about these theoretical frames is an expressed structure with the notions of uncertainty, probability and surprise.

Aside from the notion of "probability," "uncertainty" and "surprise" are not treated as expressions of lived-experience. In particular, "uncertainty" appears to be equated with an inability to know something with certainty. "Uncertainty," however, from a phenomenological point of view, is an expression of a lived-experience rooted in a careful deliberation over time of a number of different possibilities.[153] To be clear, the prefix of "un-" does not, in this case, negate the lived-experience of "certainty." That is, uncertainty is not about not being certain.

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[151] J. L. Casti, *Reality Rules: Picturing the World in Mathematics*, 2 vols. (New York: Wiley, 1992), Vol. 2, 259.

[152] Ibid.

[153] Kagan, *Surprise, Uncertainty, and Mental Structures.*

What is clear is that uncertainty is not to be equated with randomness, which Casti expresses as "uncertainty ≠ randomness."[154] Furthermore, Casti takes it as a "fairly evident fact" that:

> *the uncertainty we feel over everyday events and situations cannot usually be attributed to the influence of a random mechanism, but appears to stem from an inherent vagueness, or lack of information, either in the linguistic description or other circumstances surrounding the situations we find ourselves in.*[155]

The "surprise" which is being measured, as with, *e.g.*, probability theory, is a numerical measure of how surprising a given occurrence of some event would be. Again, this is not an actual measure of some lived human experience of surprise.

To frame an understanding of the lived-experience of surprise, one might consider Casti's proposition. He asks his readers to consider that surprise is an emergent result arising from a discrepancy between the behaviour of some open system through its interactions within the larger context of that system (*i.e.*, the world) and the behaviour of a closed system (*i.e.*, human thoughts) to those same interactions. In other words, the discrepancy arises through some difference between what is "there" to be experienced and what could have been expected–even on an unconscious level.

Although Casti suggests that complexity arises from a potential of bifurcation, it is a notion that implies surprise or error.[156] Specifically, from a particular complexity frame, the next section will attempt to frame surprise as a lived-experience in mathematized terms that seem fitting for a catastrophe-inspired model. This is not a catastrophic event in the ordinary everyday sense of the notion, but a catastrophe in Thom's sense of catastrophe. The question of surprise, which I speculate to be an emergent phenomenon, however, cannot be accounted for in such a model. That is, the "novelty" of a surprising moment of unexpectedness cannot be addressed through a catastrophe model. In this manner, surprise as an emergent phenomenon could be better addressed through the theoretical framework of self-organized criticality. It would seem, however, that the "experience" of surprise can still be accounted for in a catastrophic-based model that shows its apparent discontinuous character or sudden discrepancies with the highly anticipated or the overly-familiar.

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[154] Casti, *Reality Rules*, Vol. 2, 259.

[155] Ibid.

[156] Ibid., Vol. 1, 25.

A Catastrophe Model

Is it conceivable that surprise could be a reflection of some catastrophic event? Perhaps. But in terms of modern bifurcation theory, a catastrophe takes on a slightly different meaning and is concerned with processes that produce or otherwise display discontinuous behaviours. While the world may be perceived as generally continuous and changing gradually, there are many physical processes that occur in the world which are discontinuous in nature. These include models of air or fluid turbulence, the differentiation of cells, the stock market, the buckling of beams, light caustics, heart dynamics and the collapsing of stars to name but a few. [157] Of course, a number of social scientists have also applied catastrophe-theoretic notions to the realm of social interactions, including topics like the dynamics of love, dreams, stress and human performance, and accident and risk analysis.[158]

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[157] *Cf.*, Ibid, E. Hopf, "A Mathematical Example Displaying Features of Turbulence," *Communications in Pure and Applied Mathematics*, no. 1 (1948), Jones and Sleeman, *Differential Equations and Mathematical Biology*, Ruelle and Takens, "On the Nature of Turbulence", Thom, *Structural Stability and Morphogenesis*, E. C. Zeeman, "On the Unstable Behavior of Stock Exchanges," *J. Math. Economics*, no. 1 (1974).

In the late-1960s and early-1970s, French mathematician René Thom framed and introduced a set of phenomenon he described under the heading of catastrophe theory, a special branch of dynamical systems theory. Technically speaking, catastrophe theory addresses the loss of stability at points of bifurcation (catastrophes) in dynamic systems. Specifically, Thom's central thesis, outlined in his seminal work *Structural stability and morphogenesis*, states that given a parameterized space and a maximum of four control parameters that may change continuously models of events with discontinuous changes may be classified according to one of seven qualitatively distinct topologies.[159]

Phenomenologically speaking, the quality of "suddenness" is a particular lived existential; in this case, it is the temporality or "lived-time" aspect of surprise that proves to be a helpful category for reflecting on its nature or essence.[160] Certainly, one cannot separate this lived existential from the others, *i.e.*, corporality, spatiality and relationality.[161] Still, it can be differentiated, and I use it here as one aspect that could inform a general shape for a catastrophic model for surprise and unexpectedness. With this idea of suddenness in mind, it is fitting to consider a theory which examines phenomena that unfold discontinuously (although not necessarily continuously discontinuous): while modeling physical systems may be easier, attempting to model surprise as a complex phenomenon could open up other possibilities for thinking about and understanding this deeply-felt human experience.

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[158] Stephen J. Guastello, *Chaos, Catastrophe, and Human Affairs: Applications of Nonlinear Dynamics to Work, Organizations, and Social Evolution* (Mahwah, NJ: Lawrence Erlbaum, 1995), David Khan, Allan Combs, and Stanley Krippner, "Dreaming as a Function of Chaos-Like Stochastic Processes," *Nonlinear Dynamics, Psychology, and Life Sciences* 6, no. 4 (2002), Sergio Rinaldi and Alessandra Gragnani, "Love Dynamics between Secure Individuals: A Modeling Approach," *Nonlinear Dynamics, Psychology and Life Sciences* 2, no. 4 (1998).

[159] Thom's classification theorem also holds true for four additional catastrophe models. Specifically, the response surfaces known as *wigwam*, *second hyperbolic*, *second elliptic*, and *symbolic umbilic* are built upon a parameterized space with five control parameters.

[160] van Manen, *Researching Lived Experience*, 101.

[161] Ibid., 105.

Self-Organized Criticality

Of course, the world is always changing. This may be an obvious statement to make. Nevertheless, human beings sometimes seem to forget this, and thoughts and phrases like "I was caught off guard" and "Why is this happening?" point to a rather mystifying thought. That is, we also seem to *forget* that the world is continually changing as are we. This is a rather puzzling paradox. Still, what complexity scientists believe about how the human brain emerges can illuminate the tension in this apparent paradox.

If the world is continually changing, then why are there times when we do not seem to notice change? How are we affected by imperceptible change? Is there something significant or special concerning those changes that we can perceive as opposed to those that are imperceptible to us? There is, perhaps, nothing special or privileged about change that is perceptible to human beings, as opposed to imperceptible change. That is, all change arises from the same dynamics: yes, in some cases, dramatic effects can happen. But more times than not, mostly smaller and more frequent imperceptible change happens.

Similar to two canonical examples–sand piles and earthquakes–surprise is a phenomenon that sometimes emerges at times of critical transformation. I shall refer to the experience "unexpectedness" as being a particular surprising moment that happens at some critical moment of transformation to distinguish it from other experiences of surprise. I do this to align my thoughts with the use of surprise in the complexity sciences as a discrepancy between expectation and experience. This allows me to make the claim that every moment is a moment of surprise. This shift in meaning is important for framing a theory of surprise in the light of the complexity sciences.

With this in mind, it can be said that the world is full of surprises. Every moment is a surprising moment. Now. Now. And, now, again. Did you notice anything surprising? To use a cliché, I wouldn't be surprised if you said 'no.' But why are we not surprised (in every moment)? Surprises happen *for* us, and not necessarily *to* us. In this manner, to be surprised means attending to our current lived embodied experiences in the world rather than large, significant human events.

Moreover, the world cannot necessarily *cause* us to be surprised without our partial collusion–particularly when we are inattentive to it, and the world fades into a background of over-familiarity. Thus, if the world is full of surprises, some are being filtered out: the human mind must necessarily forget some things. In fact, the brain must *learn* to forget. Also, the brain has developed in such a way as to bring forth a mind that functions in the world with expectations: this allows human beings to constantly adapt to a changing world. Otherwise, to use a computer metaphor, the human brain would "overload."

I still wish to hold onto Casti's notion of surprise. That is, surprise is some result arising from some discrepancy between the behaviour of some open system through its interactions within the larger context of that system and the behaviour of a closed system to those same interactions. The measure of such a discrepancy will be important to describing further a self-organized critical model of surprise, although I will not–or rather cannot–say what such a thing would be. Although the measures of such discrepancies have been useful and used in classical probability studies of surprise, I will refer to such measures in more of a conceptual manner. That is, I will use the idea of a fractal as a way of thinking about how one might "measure" of the phenomenon of surprise.

The emerging thinking behind self-organized critical phenomena has shown that many phenomena evolve and emerge at some "critical state" where change in the phenomenon, brought about by some disturbance, can lead to an event of any size. Earthquakes and avalanches tend to be the canonical examples for such phenomena. And, for ages, human beings have thought that major events involving phenomena like earthquakes and avalanches were special events. Indeed, they can be special; however, they are not technically unusual from similar smaller events, although the significance of them may be because of emotional reasons and not "rational" ones. In fact, it is the same evolution to such a state that gives rise to a large avalanche that brings about smaller ones. The dynamical interactions of self-organized critical organizations create an organization capable of change at any time. The size of such changes, however, will vary in a distribution referred to as a power law.

The point, however, is this: I would conjecture that surprises could happen more often than we realize and come in a variety of "measures"–in many sizes, small and large. That is, the relationships between the "size" of a surprise and the quantity of such surprises could be expressed mathematically as a power law–at least hypothetically. Graphically, such distributions looks like straight lines on a double-log coordinate scale: as the size of the measure increases, the fewer of such measures there will be, and, thus, the collection of data points resembles a straight line. Analogically, then, we experience more surprises which, if they could be measured, are small in nature compared to surprises that "stand out more" and felt as lived-experiences.

Of course, what remains observable or experiential, as with a surprise, depends upon our capacity to perceive. Thus, we do sense the trembling the ground beneath our feet all of the time. Tremors happen constantly, but so many remain below our own thresholds of perception. When a tremor is felt, therefore, it is perceived to be a special event. Similarly, I claim that we are surprised more often than we realize for the exact same reasons, but our own physiology is complicit in removing or filtering out surprising possibilities as well through mechanisms such as perceptual completion, for example.

A self-organized critical view of the nature of surprise then has this to say: "surprise" is an emergent phenomenon that manifests itself at a level different from the interactions of (at least two) different systems, as well as the systems themselves. Through the interactions, the possibility of surprise is brought forth through some "push" into novelty. At some perceptual threshold, the experience of "unexpectedness" is felt: below that threshold, surprises of "all sizes" or 'measures" continue to happen, although they remain outside of the narrow bandwidth of human consciousness. Such subliminal surprises, nevertheless, become a part of who we are as we are a product of our history. In this manner, human beings become prepared for further surprises. In other words, surprise is possible because of our embodied history, and when prompted, a surprising moment happens for us, and not to us. So, in fact, while many types of organizations attempt to remove the possibility of being surprised, surprise is actually something that will happen in spite of our efforts to eliminate it. Surprise is about an organization's way of being able to adapt to change. Becoming rigid and stable is no way to adapt to change, however, encouraging diversity and possibility through interactions in dynamic ways and in dynamic spaces suggests a more promising way to deal with a constantly changing world. These, we will see, are some important conditions for structuring healthy learning organizations.

In the remaining part of this work, I will examine the notion of a healthy learning organization and my own experiences with working in such a setting. The final chapter of this work will present some final thoughts on comparative dynamics in the context of educational concerns.

Chapter 5

LEARNING ORGANIZATIONS

Toward a View of Healthy Learning Organizations

> *Learning is an emergent property of a CAS [Complex Adaptive System]. The overall system learns collectively as individual agents within the system learn. This is not an activity that can be dictated and controlled ... but it can be encouraged and facilitated. We can't force learning, but we can take actions that make learning more likely to occur.*[162]

The notion of an organization as a coherent, dynamic pattern of coordinated action encompasses not only organizations at the scale of social interaction. It is not just or simply restricted to "social organizations," but also includes the biological, the psychological and the ecological. Organizations come in a variety of different shapes and sizes, to be sure, for a variety of different purposes, and one thing about social organizations is that they are purposeful. They exist for business and corporate engagements, political governance, cultural expression, the betterment of individual and population health, the learning and education of people, the satisfaction of basic needs, and so on.

A number of important issues and notions must be attended to first: namely, what is an "organization?" What is "learning," and what might a "learning organization" be? And, last, the notion of 'healthiness" as an aspect of organizations deserves some attention as well. These questions will be addressed throughout this chapter. They will be addressed within two different contexts. First, I have been fortunate enough to spend considerable time working with a non-profit healthcare organization in the United States. The organization is called Plexus Institute, and I will focus specifically on the organization's learning and educational events and offerings as a member of the community. The second context, the context of education, will be considered as well, and compared and contrasted in light of the educational offerings within Plexus Institute. Once done, the previously raised questions about healthy organizations and learning will be discussed in the larger context of education.

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[162] Brenda Zimmerman, Curt Lindberg, and Paul Plsek, *Edgeware: Lessons from Complexity Science for Health Care Leaders* (Dallas, TX: VHA, 1998), 200.

What Is An Organization?

What makes an "organization" an organization? Neuroscientist, Scott Kelso suggests that organizations, including biological organizations, have directed purposes.[163] Some individuals consider organizations to be explicitly about human beings, dropping the "social" as a descriptor or modifier of organization: in this manner, individuals like Niklas Luhmann portray organizations solely as social organizations, writing that "some systems have acquired a negligible significance in modern society as 'formal organizations,' which regulate their boundaries primarily by membership roles and admission to membership and which handle themes as something that can be expected from the system members because of their membership."[164] One can see in Luhmann's comments that this notion of organization would appear to reach across into the biological and the social. Either way, there is a sense of directed purpose or intentionality which is present in the functionality of the organization no matter what "kind": this is already captured in etymological roots of the term as being a tool or instrument.

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[163] Kelso, *Dynamic Patterns*, 138.

[164] Luhmann, *Social Systems*, 196.

The notion of an organization is not without its difficulties. As a group therapist and a Professor of Management at the University of Hertfordshire in the United Kingdom, Ralph Stacey discusses some of the conceptual challenges that the concept of "organization" creates.[165] The first difficulty, whether pedantic or not, is with the reification of social organizations, rendered as "wholes," which invokes a particular spatial metaphor where "insides" and "outsides" are conceived as separate and separated by a "boundary." Framed in this manner, Stacey suggests that thinking of organizations in this way "immediately establishes hierarchical levels."[166] As such, there continues, as many past and contemporary discourses do, a wide range of commitments that cut up the world into different hierarchical levels, demanding or otherwise requiring different ways of understanding each level of organization.

In many ways, it does make sense to shift away from spatial framings (as social organizations are often described or thought of as bodies, metaphorically speaking, of course) to temporal understandings. This is not merely some means to sidestepping some of the apparent objections that some might have of spatial conceptualizations of organizations. To be sure, the notions of "inside" and "outside" have little relevance to temporal processes of human interactions. That is, human actions are not particularly well suited for spatial descriptions. Human beings walk, talk and think, and to remove those kinds of interactions from the confines of a company, institution or school–any "organization"–suggests that there can be no "part" of an organization "left behind." It might appear, then, that an organization is simply the "additive accumulation of individuals."[167] There is, however, no separation or distinction that can be made in our day-to-day experiences. That is, there is no gulf between the individual and organization. One cannot exist without the other where both arise from the same complex collection of human interactions.

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[165] Stacey, *Complexity and Group Processes.*

[166] Ibid., 279.

In spite of these difficulties raised by individuals like Ralph Stacey and Norbert Elias, complexity science ideas rather than systems thinking provide a domain of concepts that work as analogies appropriate for thinking about human interactions. Specifically, the concepts of self-organization, local interactions and emergence, as terms frequently used in the complexity discourses, are fitting for understanding human interaction without utilizing systems thinking and concepts. Complexity is an appropriate lens through which to look at "organizations" as a means to understand coherent patterns arising from self-organizing local interactions bringing forth patterning activities of human bodies.

Thoughts on "Learning"

There are no shortages of questions and commentaries about the notion of "learning." Attention to discussions about learning can be found across a number of different domains such as psychology, cybernetics, education and more recently in areas of study like artificial intelligence and neural networks.[168] As theories of cognition are concerned, each domain comprises a wide range of intellectual and conceptual commitments that address concerns about how the mind works, the nature of knowledge and how it might be that human beings learn. It is not the intention of this section to explore this in any extensive fashion; however, a particular meta-conceptual distinction will be made and briefly explored at this time.

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[167] Norbert Elias, *The Society of Individuals*, ed. Michael Schroter, trans. Edmund Jephcott (New York: Continuum International Publishing Group, 2001).

[168] *Cf.*, Britzman, *Practice Makes Practice*, Davis, Sumara, and Luce-Kapler, *Engaging Minds*, Kelly, *Out of Control*, Kelso, *Dynamic Patterns*, Nørretranders, *The User Illusion*.

In educational discourse, the distinction between theories of cognition which has been described as "complicated" versus "complex" has already been discussed elsewhere.[169] Nevertheless, it is fitting in this context to re-present this distinction briefly since complex phenomena are the focus of this work. The characterization of learning theories, reflections of certain technologies and metaphorical frames, show how learning theorists have understood, adopted and used particular learning theories which span the human imagination for the mechanized framings and more biologically-oriented frames of learning. Specifically, various images of learning, as well as images of organizations, include not only the mechanical and biological, but many other images which include the brain, cultural settings, political systems and the psychic.[170] In many cases, these different frames fall under either the categories of "complicated" or "complex" learning theories. More importantly and for the purposes of this work, it should be noted that education scholars Brent Davis, Dennis Sumara and Rebecca Luce-Kapler have framed in their collective work how various theories of cognition might be categorized in a similar manner.[171] Briefly, the distinction between the two different conceptual frames will be examined now.

Complicated Learning Theories

Historically, a variety of different phenomena have been framed and understood in terms of mechanical and linear cause-and-effect interactions.

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[169] Davis, Sumara, and Luce-Kapler, *Engaging Minds*.

[170] Morgan, *Images of Organization*.

[171] Davis, Sumara, and Luce-Kapler, *Engaging Minds*.

These phenomena have come to be described as "complicated," a notion that has only relatively recently come into being through complexity-related discourses. In the context of "learning," it is not so much that learning is "complicated," but rather that certain interpretations about learning are based upon assumptions that are more appropriate for a mechanical orientation to cognition. This is not so much to say that certain theories are wrong and others are right. Like metaphors, theories can also highlight and hide certain aspects of the phenomenon under consideration. As the roots of the word suggest, a **theory**, from the Greek, *theorein*, "to see," is a way of seeing and of understanding something. And, just as human sight involves a great deal of filtering and perceptual completion, metaphorical frames and theories also bring to light and hide aspects of the world.

There are a couple of predominant 20th-century learning theories that fall within this category of complicated learning theories: *behaviourist* and *mentalist* learning theories. To be certain, both classes of learning theories reflect different orientations, although there is one key assumption that they share which is the isolatable nature of knower and known. In other words, the assumption is that there is a separation between the internal thinking of individuals and the outer realities as well as a division between one's mind and one's body.

As far as education might be concerned, from the point of view of educators or researchers, behaviours as opposed to human thought are more accessible through direct observation and are therefore more open to "direct intervention." With the belief that human behaviours are "lawful and determined," the training of individuals–especially in the name of education–has led to instilling the notion that "long chains of complicated and counter-intuitive behaviours can be taught through careful administration of rewards, promises of reward, punishments, and threats of punishment."[172] As such, learning is not simply limited to the consciously formulated structures of a learning event, but also the unnoticed or unconscious structures of one's context.

Put differently, learning under the banner of behaviourism has been reduced to certain recommendations that boil down to issues of command and control structures. Knowing and learning are deemed accumulative and linear in nature, and the behaviour of human beings is subject to control and prediction. Again, it must be kept in mind that behaviourism is not wrong, but is sometimes inappropriately applied. It has proven useful in terms of affecting non-conscious processes and certain automatic behaviours, but for more complex, that is, not "complicated," behaviours, behaviourism has proven to be more problematic than useful with the complexities of learning.

Outwardly expressed behaviours may sometimes be considered to be indicators of learning, however, the emphasis on the observable and measurable also shifts one's focus away from internal processes or mental phenomena. And, just as there are certain difficulties with behaviourist theories, mentalist learning theories are not without their own complications.

Indeed, outward visible patterns of activity might provide some evidence for learning, but 20th-century obsessions have also suggested a need to focus on internal processes of cognition as signs of learning.[173] Mentalist theories of learning with their attendant metaphors, the computer being one of the more popular images for the brain and the mind (as if they were the same thing), reduces learning to a matter of an individual having the right representations of the world "out there" where the subjective model matches the real thing. Put differently, mentalist models of learning are about a preservation of knowledge through representations of an external world in terms of inner digital encodings embedded in a neural network to follow through on a digital metaphor.

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[172] Ibid., 56-57.

[173] Ibid., 60.

Aside from the more obvious difficulties of the mentalist metaphor of a computer (*e.g.*, being "hard-wired"), such a frame posits a "taking in" of information. The fact that this is a metaphor, first of all, seldom occurs to many people, and it is frequently taken as obvious, and a direct description of mental phenomena.[174] Moreover, this kind of "machine metaphor" gives us "a conception of the mind as having an on-off state, a level of efficiency, a productive capacity, an internal mechanism, a source of energy, and an operating condition."[175] Neither the brain nor the mind seems to work in this way as framed by the metaphor of a computer.

Recent studies in the field of cognitive science have challenged mentalist conceptions of thought and reason, rendering them inconsistent with what some cognitive scientists now believe. George Lakoff, for instance, reports that "the mind is inherently embodied. Thought is mostly unconscious. Abstract concepts are largely metaphorical."[176] That is, conceptions of cognition–in this case, the notion that the mind as a machine–are largely metaphorical. Furthermore, people have spoken of language and learning framed by what Michael Reddy calls a "conduit metaphor" where ideas are objects, expressions are containers for those ideas, and communication is about an exchange of those ideas.[177] The literalized metaphor of the mind as machine, therefore, has cast a mentalist view of cognition as complicated. The difficulties do not end here with the kinds of challenges that a literalized metaphor creates. With current tendencies to categorize individuals as certain types of learners, the transformation of ideas and concepts into particular kinds of experiences for the visual or auditory learner, for example, perpetuates the idea of congruent inner models that correspond to the external world.[178] Open the mind. Insert the conduit. Send through the bit of information. And, then, something has been learned that matches the external world. In the end, mentalist theories of knowing have reduced and dampened many complex conceptualizations of learning organizations, irrespective of the scale.

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[174] George Lakoff and Mark Johnson, *Metaphors We Live By* (Chicago, IL: University of Chicago Press, 1980).

[175] Ibid., 28.

[176] Lakoff and Johnson, *Philosophy in the Flesh*, 3.

Complex Learning Theories

In addition to the predominantly complicated 20th century theories of learning, educators and learning theorists have also addressed cognition using perspectives variously described as enactivist, ecological, organic, holistic and complex.[179] In comparison to complicated learning theories, these kinds of theories of cognition attend to the embeddedness of interdependent relations rather than separable and isolatable "parts." Implicit in complex learning theories is the need for participation where not only our bodies are a part of the world, but so are our thoughts in an on-going co-evolution. But more importantly, complex learning theories acknowledge and embrace a certain measure of unpredictability.

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[177] Lakoff and Johnson, *Metaphors We Live By*, 10.

[178] Davis, Sumara, and Luce-Kapler, *Engaging Minds*, 61.

[179] Ibid.

The dynamics of complex systems are quite different from complicated systems. Hence theories of cognition, whether complex or complicated, describe learning (and hence teaching) differently as well. In particular, terms like "interconnected," "interwoven," and "interacting" might be appropriate for certain machines and the parts therein, however, they fail to recognize the dynamics of relations. For this reason, "interdependence" is more appropriate as it hints at the ways in which parts may influence others.[180] Put differently, learning is about "dependency" rather than "determinacy."

Within the field of education, a number of complex theories of learning can be identified, ordered according to "scale" and focus of complex form, that are linked metaphorically to the "body" as a focus of inquiry. Beginning with the smallest "body," these include constructivist discourses, social constructionism, critical and cultural discourses, and ecological theories of knowing.[181] As such, learning is always and already embedded in and across these different scales, from the individual to larger complex collectives like social organizations, cultural bodies, and life itself. Of course, this notion of learning also extends in the other "direction" towards the "microscopic" with physiological subsystems of the human body participating in a similar fashion to other "knowing bodies" or "learning organizations."

What is a "learning organization?" One possible answer is that "a learning organization intentionally uses learning processes at the individual, group, and system level to continuously transform the organization."[182] Recent descriptions of what a learning organization is point to notions seemingly compatible with the biological organization of human beings. Simply put, a learning organization–whether or not the organization is viewed in biological or social terms–reflects a complex form that can adapt to its changing context.[183] The "learning," moreover, is something that unfolds across a number of different scales all-at-once that include the individuals of the learning organization, collectives of individuals that form work teams, and the larger organization that emerges from these collectives (of collectives).

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[180] Bar-Yam, *Dynamics of Complex Systems*, 12.

[181] Davis and Sumara, "Curriculum Forms," 838.

[182] Nancy Dixon quoted in Ibrahim Gogus, "Becoming a Learning Organization at Oracle," *Knowledge Management Review* 6, no. 4 (2003): 12.

In the final section of this chapter, I offer some insights into my own experiences of working with one particular "learning organization," connecting how I have come to understand my experiences through complexity science concepts, comparative dynamics and healthy organizations.

Lessons from a Learning Organization

Organizations come in a variety of "shapes" and "sizes." In terms of having a directed purpose, organizations also serve the needs of people that encompass people's interest in and for big business, industrial and technological production, the service industry, politics, education and health. But not everyone would say that all organizations, and specifically people's experience of them, are fitting of the notion of a learning organization. That is, people often describe their experience with organizations, for instance, places where they work, as "hierarchical," "rigid," "like a cog," and so on. Metaphorically, these descriptions sound almost mind-numbing. Learning organizations are and must be dynamic in rather specific ways.

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[183] Brent Davis and Dennis Sumara, "Learning Communities: Understanding the Workplace as a Complex System," in *New Directions for Adult and Continuing Education* (2001), 88.

In the fall of 2000, PI as a non-profit healthcare organization opened its doors. With the early efforts of Curt Lindberg and a number of healthcare professionals and colleagues, their concerns with various aspects of healthcare and ultimately with the health of human beings became the early impetus for the institute.[184] As part of their work together, they began to study the emerging ideas from the paradigmatic field of complexity science with influences coming from the work of many seemingly disparate disciplines. These include physics, chemistry, biology, mathematics and medicine, psychology and organizational dynamics and the writings of a number of prominent scientists, scholars and researchers: Murray Gell-Mann, Ilya Prigogine, Edward Wilson, Ary Goldberger, John Holland, Herbert Simon and Ralph Stacey, to name some.

Realizing the need for an expanded mindset that could include an understanding of living, dynamic healthy organizations, the early founders of PI took up a concerted effort to study and know more about how order and novelty emerge in the world.[185] In fact, most of the biosphere or living world functions in a manner which is, quite different from the logic and function of machines, more towards the non-linear, adaptive, and constantly changing. Science has certainly learned a great deal about the world by tending to the "parts" of the world, however, even more is being learned by tending to the nature of interactions of the "improvising parts" of the world.[186]

Questioning the notions of leadership as master controller, learning, and physiological health, a significant part of the institute's work explicitly rests upon the notions of decentralized control and self-organization, to name two important concepts from the complexity sciences. Relationships, as generated by interactions and conversation created through an attention to different scales of interaction and diversity, as shown through the organization's members and conference attendees, are two other principles which the institute consciously and actively uses to create the kinds of opportunities necessary for people to learn, adapt and create the kinds of necessary conditions for healthy organizations, which, to be clear, include the biological, social, cultural and ecological.

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[184] Curt Lindberg et al., "Plexus Institute.Emerging," (New Jersey: 2002).

[185] Ibid., 7.

[186] This notion of "improvising parts" comes from conversations I have had with bass jazz player and organizational theorist, Michael Gold, of Jazz Impact (www.jazzimpact.com).

Taken together, a complexity science framework has shows how the experiences PI members and conference attendees could potentially be understood and/or transformed. To that end, the work of PI has come to reflect the following ideals:

- The capacity to generate change is a distributed property among all members of an organization, including the capacity to prevent change;
- The most critical aspect of an organization are its relationships;
- People in organizations simultaneously affect and are affected by each other; no one, including the formal leaders, can stand outside the organization. Everyone's behaviour affects the organization;
- All members of an organization can only act locally;
- In complex systems, detailed planning from the top is best replaced by minimum specifications and appropriate autonomy for all to participate in a self-organizing fashion;
- What an organization can accomplish cannot be understood without first understanding its history, and

Among the many factors that affect organizational creativity are information flow, diversity, connectivity, power differentials and anxiety. Most organizations have too little information flow and diversity and too much difference in power.[187]

With some of the early insights that complexity science research and thinking were providing for Lindberg and his early collaborators, they began to see how complexity science ideas could "inspire new ways of helping healthcare organizations become more responsive to the needs of people, families, communities and their own employees."[188] Although the initial group was loosely created, it operated according to the very principles that had brought them together. To create robustness, the group deliberately self-organized into continually changing small teams to share experiences and insights, and in time, what the group had learned began to spread to other networks of which its members were a part. Consequently, many people and organizations began applying new ideas inspired from complex systems.

From the beginning, then, as the story is told, a number of principles can be seen at play. For instance, through the group's interactions, a number of important connections and relations emerged over time. But, of course, no organization emerges in isolation over time, as the connections stretched "beyond" the smaller work groups and the entire fledgling group itself. Put differently, through the group's willingness to share information and stories with one another, they were able to become something much bigger. That is, through their interactions, some very important relationships could emerge. And, while relations may be important, the diversity of the early founders of PI was also an important consideration. Not only did Lindberg, who previously worked with the Veterans Health Administration (VHA) in the US, manage to pull together some wonderful colleagues from a number of different organizations and backgrounds within the larger US healthcare system, but he and others worked deliberately to bring others quite different from themselves into the mix. The early members of PI have over time led to many other executives, students, artists and writers, scientists, nurses, educators, physicians, and government officials joining and participating in the work of the institute.

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[187] Lindberg et al., "Plexus Institute.Emerging," 9-10.

[188] Ibid., 11.

When the organization officially formed in the fall of 2000, one of the founding trustees of the fledgling institute, Bob Shapiro, made the following observations, which were steadily being seen by others in organizations of all kinds, to help guide the work of the institute:

1. At all levels, crises afflict the world around us. Many of these crises are closely connected to our controlling and mechanistic language and concepts, which are reaching the limits of their effectiveness.
2. People sense the truth of this limitation. Yet paradoxically, many of the people discomforted by the mechanistic thinking so prevalent in our organizations are people who occupy positions of power and control.
3. A new set of ideas and tools are becoming available to help ameliorate this tension, namely, the principles of complexity and a new understanding of the laws of nature.[189]

As an example of how the institute has put these ideas from the complexity sciences into practice since its inception, this section will end with an exploration and reflection of how it has designed and implemented its many educational conferences and workshops since its early beginnings. Since PI took its first steps, it has helped to create a significant number of networking and learning events for scientists and leaders from many different kinds of organizations, including corporations, healthcare, government agencies, universities and many community-based organizations. Moreover, the institute has continued to design its educational offerings with complexity principles in mind: flexible workshop and conference formats are created to facilitate interaction and self-organization; participants shape these events by offering issues for discussion and sharing stories of their individual experiences; the atmosphere is welcoming, inclusive and informal; numerous small group discussions emerge at the initiative of participants.

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[189] Ibid., 13.

By framing its educational offerings in this fashion, many benefits have been recognized by the institute and its members. New ideas and insights are easily picked up by conference attendees. In turn, and oftentimes during a conference event, these new ideas have become the basis for new initiatives in their own organizations and communities. On one such occasion, attendees at the first Plexus conference I ever attended decided that concerns about the place and role of uncertainty and surprise in organizations were important enough to address that they agreed to put on a conference gathering on this theme. Working with PI, the conference "Uncertainty and Surprise: Questions on Working with the Unexpected and Unknowable," was launched at the University of Texas at Austin in April 2003. With Reuben McDaniels from the Department of Management Science and Information Systems in the McCombs School of Business pulling together approximately 100 international participants and support from organizations like the Ilya Prigogine Center for Studies in Statistical Mechanics and Complex Systems, scholars and researchers like Scott Kelso, Bruce West, Karl Weick and Peter Allen came together for three days of discussion.[190] These initiatives and projects in turn have become a wonderful new source of stories for the institute's future conferences, attracting new members all around the world. New relationships have emerged which have lead to the formation of many other educational initiatives including local groups (referred to as "fractals"), learning networks, electronic listservs, a newsletter and research.

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[190] Sadly, Ilya Prigogine, who was scheduled to attend, was gravely ill and unable to attend. A little more than a month after the conference, on May 23, 2003, Nobel Laureate, Ilya Prigogine, died at the age of 86 in Belgium.

In terms of planning for its educational offerings, PI has put into practice many concepts taken from the complexity sciences. Unlike many more traditional conferences, PI works to ensure a high degree of interaction across many different scales of organization. These scales of interaction have been described as three archetypal learning structures: the cave, the watering hole and the campfire.[191] Put differently, these structures include time for self-reflection, the spontaneous conversations that form during breaks, meals and smaller break-out sessions, and occasions for the entire group for formal presentations (which are seldom "formal" and always seem to invite interaction throughout).

Drawing upon the work of people like Ralph Stacey and Patricia Shaw, the interactions open up a large "space" for story-telling and conversation.[192] Highly encouraged, the stories of people's experiences point to occasions where practice and theory emerge together, fitting of a complexity interpretation. In the gesture-and-response structure of conversation, therefore, interactions bring forth more interactions; shared stories begin to resonate amongst people; and local patterns of experience start to emerge sometimes giving rise to larger more "global" patterns. Thus, through the group's interactions and the redundancy of shared knowledge and experience, the possibility for new emergent ideas and initiatives–a reflection in the mutually influential relation between ideas and actions–can unfold.

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[191] David D. Thornburg, "Campfires in Cyberspace: Primordial Metaphors for Learning in the 21st Century."

[192] Patricia Shaw, *Changing Conversations in Organizations: A Complexity Approach to Change* (London: Routledge, 2002), Ralph D. Stacey, *Complex Responsive Processes in Organizations: Learning and Knowledge Creation* (London: Routledge, 2001).

One final thing needs to be acknowledged and further emphasized at this point: diversity. Without diversity, these events would be remarkably like some of the computer simulations that I have worked on. Whether I create a simulation to model the gathering of wood by termites or the flashing of fireflies, the models ALWAYS produce a single pile of woodchips and a single pulsating group of fireflies. And, while a particular outcome might arise, that is the only possible outcome. Without diversity, therefore, the possibility for novelty, new insights and on-going learning is not likely to happen or is apt to be diminished. Even with the possibility for a group of individuals to adapt, a homogenous group is not apt to evolve in anything else. At the different workshops and conference that PI has convened, the social diversity has given the gatherings what it needs to facilitate on-going conversations. In addition, while PI is historically rooted as an organization in health and healthcare, many of these events also have provided the occasion for others from outside of healthcare to contribute and learn from others as well. Thus, topics like leadership and innovation, for instance, are not only timely and appropriate for many of PI's gatherings, they are fitting for people who identify with professions outside of healthcare.

It is fitting to end this chapter with some of my own personal reflections, in an autoethnographic sense, on the many and diverse conferences over the past two years of my work with PI. To be clear, while my role at PI has focused on working with others on the design and planning aspects of our conference offerings, during the many gatherings at various locations across North America, my experience has been as a fully participating member of a diverse community.

Although many things about Plexus gatherings have struck me as interesting, one thing that I have always noticed is that each event has brought together a diversity of participants. Certainly, PI's historical roots in health and healthcare bring many doctors, nurses, and clinicians to our events, but consultants, organizational theorists, managers, quality assurance specialists, biologists, computer scientists, communications scholars and many others have joined us over time in very rich conversations. This is perhaps a superficial example of diversity at work, but it has always marked a necessary and important step in launching our very successful gatherings. Aside from the fact that I have been privileged to meet so many interesting people, I have come to know many who have shown great wisdom, humility and openness to sharing with others who they are and what they know. Still, I have found that the diversity of our participants brings together a wealth of different experiences that serve as potential catalysts for new shared insights. In the most unexpected of ways, I know that I have been transformed in some significant way through many, and sometimes seemingly small, interactions with my conference colleagues.

While participants might come to a conference gathering on diffusion or complex responsive processes or storytelling or healthy communities, the presence of local issues and questions that participants bring and share with others creates the kinds of connections across a wide range of organizational scales and phenomena. That is, there is a shared sense of concerns, and the physiologist learns something from the computer modeler, the social scientist, the neuroscientist, the social worker and the ecologist and vice versa. As an educator with a strong interest in complexity, I have learned from my friends and colleagues from the larger PI network and incorporate a variety of new ideas into my own scholarly work which is, in part, seen in this piece. Certainly, Plexus educational offerings have provided me with the kinds of opportunities to learn and make "deeper" connections in my on-going learning. Of course, I have learned plenty of things in many other contexts, but something very powerful seems to happen during these gatherings when people come together at Plexus events.

I certainly have learned quite a bit by listening to special "faculty" and "guests" in formal large group presentations and the smaller break-out groups provide additional opportunities to learn. But scheduled breaks, meals, after-conference walks, drinks at the bar, and even moments where I have "skipped out" of a session with another participant have provided me with the most exciting and sometimes intense conversations. What I notice about my own experiences is how the wonderfully rich opportunities that arise in the accidental moments of impromptu conversations create some of the most astounding insights. Like the proverbial water cooler at the office, these occasions are the perfect interactions for sharing "vital" information and ideas. To say that I feel alive would not be an exaggeration. The group comes alive during these informal sessions. And, when the larger group and breakouts reconvene, the lively conversations have a way of propagating through the larger group.

In addition to the sharing of new ideas and creating new insights, the loosely structured interactions of the group lend themselves to the formation of other on-going networks and relationships that continue long after the conference. I have found as a result that I have a rather strong group of relations with others of different backgrounds with whom I continue to speak, collaborate and call upon for a variety of reasons every now and then. The strength of these relations and the larger weaker connections with these individuals brings me into contact with an even larger network of people around the world.

If I were to imagine a differently structured event without these conditions present, something would feel very wrong. For me, there probably would be very few emergent relationships, fewer insights and a strong sense of being disconnected from other people and other ideas. With these reflections and descriptions of PI educational offerings, I want to suggest that such experiences and ways of organizing or creating the conditions for opportunities where people share important new ideas and problems reflect the qualities of a learning organization, and, I would argue, a healthy learning organization.

Chapter 6

HEALTHY LEARNING ORGANIZATIONS AND EDUCATION

Health and Self-Organization in Learning Contexts

> *Today, the schools in this country are model industrial schools, and have been for most of a century. They have carefully modified themselves in step with the modifications that occurred in the industrial economy, and they have served that economy well. But the schools as they exist are no more relevant to the post-industrial life style into which America is headed than are any of the other trappings of the industrial society. And, more important, the existing school system is not even adequate today....*[193]

Following a few different disciplines and theoretical influences, especially the mindset and conceptual underpinnings of complexity science, I have made a series of arguments in an attempt to articulate a description of and a possible means for creating healthy learning organizations of varying scales. The implications for thinking about organizations in this manner, following and using complexity science principles, are profound and potentially useful for inquiring into a wide array of matters ranging from leadership issues; learning, play and creativity; ecological matters and urban planning; and, issues pertaining to biological, community and population health. All of these matters, as well as others that one might imagine, hold some relevance for education and the project of schooling.

The complexity sciences have opened up a formalized view of certain phenomena that are often compared to and contrasted with two other classes. That is, paradigmatic complexity, as a class of dynamic forms and processes, has arisen, to some degree, as a scientific discourse in conjunction with the classes of "simple" and "complicated" phenomena. Conceptually, each phenomenon is shaped by particular assumptions, and certain tools and approaches appropriate to each class of phenomena have been developed over time through increasingly sophisticated technologies and tools. In the context of complex systems, scale-free patterns, non-linear interactions and the principle aspects of emergence and self-organization are at the heart of so many phenomena which encompass the very small and the very large. Starting from a basis for understanding the dynamics and forms of healthy physiological phenomena, the notion of health in an analogical sense becomes a possible frame for understanding and creating conditions for particular kinds of social organizations, including classrooms, schools and communities.

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[193] Daniel Greenberg, *A New Look at Schools* (Framingham, MA: Sudbury Valley School Press, 1992), 105-06.

The notion of a healthy organization is, therefore, fitting as a description for a wide range of phenomena viewed under the umbrella term of "comparative dynamics." In fact, complex, living organizations manifest themselves in a wide range of possible forms and behaviours in health and sickness–even more so when they are "healthy." In other words, fractal patterns and non-linear interactions, and the notions of emergence and self-organization are, generally speaking, aspects and features of healthy organizations. The contrapositive–that unhealthy organizations lack or are otherwise gravely reduced in their scale-free patterns or non-linear interactions–is, for many attentive to the biological health of people as individuals and collectives, an observable phenomenon fitting in an analogical manner for human interaction in a variety of different social domains.

In the broad context of education, the notions of healthy learning organizations and comparative dynamics open up the possibility for some compellingly different stances and perspectives for thinking about a number of different aspects of education. These include learning, and its relation to the identity, practices and knowledge of learners; classroom dynamics; the framing and understanding of school subjects; curriculum design; pre-service programs for new educators; the influences of community and physical space; and, leadership to name some. This list, I imagine, could be extended. To be certain, however, it is not possible to cover each of these topics in any great depth, however, some final thoughts will be made here which address in brief some of these issues and concerns for education as a healthy organizing structure. Specifically, I will give some consideration to some ideas related to learning, and school and classroom dynamics. Some further consideration with also be given to curriculum, physical space and leadership as thought experiments, speculating on how such things might be viewed when considered in light of a comparative dynamics approach and a health framework.

On Learning

Human beings as living, complex organizations are always and already learning. Although it is sometimes suggested or implied that learning only happens

in educational settings identified as schools, colleges and universities, for instance, learning is a process that gives rise to many complex human expressions from birth until death. From learning to walk, talking, doing arithmetic and reading, driving the family car for the first time, fitting in with particular cultural norms, and so on, human beings are learning all the time. As John Holt reminds us:

> *The trouble with talk about "learning experiences" is that it implies that all experiences can be divided into two kinds, those from which we learn*

> *something, and those from which we learn nothing. But there are no experiences from which we learn nothing. We learn something from everything we do, and everything that happens to us or is done to us.*[194]

Reducing learning to a set of well-defined activities, identities, relations and behaviours as understood within the context of formal schooling can create some problems for what is to be done or can be done. Moreover, and generally speaking, the implications for viewing learning as anything but a complex process are bound to create problems in and concerns for various theoretical reasons and practical purposes.

One might imagine a particular image at this point as a representation for thinking about learning as a well-defined collection of activities, identities, relations and behaviours. The image here is more towards a thermostat rather than, say, some living structure as a metaphorical description of learning and teaching. Descriptions of teaching and learning, it sometimes appears, tend to resemble the actions of the canonical cybernetic structure of the thermostat. But can human beings think of and structure other types of "learning organizations" that resemble the image of the human brain rather than, say, a thermostat?

In the language of cybernetics, then, it could be suggested, in a rather simplistic fashion, that many organizations seem to exhibit a single-loop learning ability like that of a thermostat. The purpose of a thermostat is to maintain a constant temperature in a room or throughout a house. In this context, as an analogy, I am suggesting that the nature of a single-loop learning organization is to keep an organization "on track." That is, like the thermostat, where there are minor deviations from particular expectations, a mechanism, in the form of a supervisor or some other authority figure, kicks in to "steer" the organization back on track. The challenge for many organizations sometimes, however, is to move towards developing, as well as sustaining, a double-loop learning organization where the organization itself has a capacity to introduce and maintain systems of review that challenge the basic operating norms of the organization. Put differently, not only can human beings learn, human beings also can learn about learning as suggested by our capacity to adapt. There is, therefore, an ability to function as an intelligent system with an inherent facility to affect what and how we learn. This is not easy to do especially for bureaucratized organizations where there are often implicit rules at work that obstruct any sort of change to the way in which the system might change. Where "staying on track," as in a single-loop learning organization, may seem to be easier to control, opening up to the possibility of a double-loop learning organization requires a bit of "letting go." Moreover, sometimes when single-loop learning organizations are reinforced, a wrong course of actions may be sustained.

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[194] John Holt, "Instead of Education," in *Deschooling Our Lives*, ed. Matt Hern (Gabriola Island, BC: New Society Publishers, 1996), 29.

But can schools function in some kind of (strongly) self-organizing manner as opposed to being more strongly directed like a metaphorical thermostat? In other words, if the brain is going to be an image for a school, then it must be kept in mind that the brain is a decentralized phenomenon, and the mind and intelligence evolve. That is, there is no pre-determined, pre-designed, or pre-planned blueprint for the brain. Of course, this runs counter to the usual frames of learning in schools that use and draw upon a clear and strong sense of direction, leadership, and control. Naturally, this is not the case for every context, every classroom, and every school. To some, including myself, this does seem rare. A large overall effect that emerges from organizing classrooms and schools in a more traditional sense is one of a set of imposed goals, objectives, and measured outcomes delivered from the upper echelons of the education system to its lower levels. Conceptually speaking, what really seem to be missing here are the constantly emerging contextual relations of learning. That is, knowing, knowledge and knower cannot be spoken of as being separable.

Today, questions continue to be raised about knowing, knowledge and knower. The inseparability of knowing, doing and being is almost a given, although it might be hard to see such a thing in the various ways in which human beings talk about the knowing-doing-being relationship. None of the "parts" of this triad are static, but there is a certain coherence or homeodynamic presence. Taken together, these different aspects of being human are persistent patterns of re-iterated interactions which "speak to" and "dance with" an always and already changing world. Change, as shown through the notions of adaptability and variability, therefore, are key elements of living phenomena, and, as such, present a very different sense of learning that demands some attention and careful re-thinking in terms of what goes on in the name of education.

Sadly, my own schooling experiences as I recall them suggest anything but. For instance, the time spent in my mathematics classes would suggest that the learning-knowing-doing relationship was no relationship at all. Mathematics was a bunch of rules applied to objects. I followed the rules. I did the math. In fact, my peers and my teachers would say that I was a "whiz" at mathematics. Somehow, I don't think that I "got it," but in some ways I did.

Not only did the symbols not "say" anything to me, I don't think that I "saw" anything either. These were meaningless, silent symbols, manipulated in some kind of mechanical manner for the purpose of solving a "problem," although the questions did not seem to be *real* problems. In the end, it was more like an already-solved puzzle which I happily worked on, most often by myself or helping others who couldn't "see" how to "do" it. Generally speaking, though, mathematics was an activity done in isolation from others. My (favourite) math teacher's words still echo in my mind: "Quietly and independently!" In general, and not just in his class, the classroom was hardly a lively place for me and my peers. I seemed quite content to work with the apparently rigid structures of mathematics curriculum, to sit quietly in a classroom where the teacher used prescriptive teaching methods, and to work on fill-in-the-blank or single step kinds of questions. As long as I did "the work," I apparently was learning something that would prepare me for the rest of my life. And, I was certainly well compensated for my "achievements" in the form of gold stars and an A in mathematics on my report cards. So, why was mathematics such a struggle for so many others?

But more importantly, what does this personal reflection say about learning, my sense of learning during those earlier years of high school, the ways in which my teachers thought and enacted particular pedagogical practices, and so on? This short and generalized reflection on my own experience of learning mathematics in high school seems quite different from my experiences at many Plexus educational events I attended. In fact, it almost seems quite antithetical, and I wonder today what I might have learned from those experiences as a teenager learning mathematics. There is almost a kind of pathological sensibility that strikes me about these kinds of experiences of learning mathematics in high school. It is not so much that everything about who I am, who I am to others, what I know and can do, and how I learn the things that I do, seems to be so disconnected and isolatable. This is not a machine of which that I am a part. The metaphor of "health" seems to be a more appropriate metaphor to use here in my own understanding of learning in general and my own past experiences of learning mathematics in school.

In the context of comparative dynamics, the kinds of dynamics and patterns under the banner of learning certainly include the kind of pathology just described. And, it is not so much that it is "bad," but rather in an analogous sense with the wide spectrum of healthy dynamics and patterns, a case for unhealthy learning. To create an image of "healthy" learning, a thought experiment shaped by the kinds of experiences I have had with PI would be helpful here.

I am tempted to say, as I look back upon the ideals announced in the earlier days of PI, that a few of those ideas stand out in my mind as being most significant for healthy learning to happen. In particular, the concepts of relationships, connectivity, local interaction and diversity seem most significant when thinking about learning. As I think about how I have learned the things I have learned over the past few years, each and every one of these concepts seems to be present. And, I think that I have learned a lot and possibly much more than if these conditions were not present.

Diversity appears in many different ways, but sadly seems to be confined, most commonly, to notions such as gender, sexuality, language, ability, and perhaps a few others attributes. The overall project of education and schooling seems to be really missing out. In an all-at-once manner, learning at PI events, for instance, entailed a lot of bumping up against many different kinds of people and ideas. Encouraged and respected, the many PI gatherings showed how learning could unfold some where between deep control and complete anarchy. Sometimes very surprising connections are made.

To be sure, not everyone learned the same things. Moreover, it could be safe to say that not everyone learns the same things in any context, nor do they learn in the same fashion. Therefore, when the presence of diversity shows itself in the kind (quality and quantity) of interactions, structures of engagement, physical spaces, and ideas and the emergent webs of ideas, learning seems to be more strongly supported. Connections are made, but even more importantly relationships are forged that allow groups and distributed collections of people to learn. There is no need to plan from the top, and individuals and collectives of many different sizes participate in a self-organizing fashion, acting locally. In the next section, I explore what this might look like in the context of classrooms and schools.

On School and Classroom Dynamics

If one were to ask people about their experiences about going to school and being in classrooms, a variety of different stories would be told. Nevertheless, certain stories seem to persist as shared recognizable experiences. For example, students of the same age sit more or less quietly in rows of desks facing the "front" of the room where an adult imparts a world of knowledge. Students do "work" for grades and are rewarded for good behaviour and following orders. As such, there is, in some sense, confusion about what goes on in schools and classrooms. As Ivan Illich remarks, we are lead to confuse "teaching with learning, grade advancement with education, a diploma with competence, and fluency with the ability to say something."[195] Put differently, "Government schooling is the explicit attempt to coerce people into accepting their appropriate place in hierarchical, industrial capitalism."[196] That this might be what is actually happening in the name of education and in classrooms is hard to ignore.

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[195] Ivan Illich, *Deschooling Society* (Saint Paul, Minnesota: Marion Boyars Publishers, Ltd., 2000), 1.

Schools are essentially state-run and compulsory institutions or systems. As such, what goes on in classrooms is strongly influenced by the direction and directives of the state and those who work for it. Education is not something that can support its own self-definition since its intent is the design of others. In other words, the capacity for the education system to self-organize is next to impossible, falling under the category of command-and-control structures.

In spite of the perceived and apparent pressures and directives of the state, the dynamics of classrooms are still pretty much influenced by what goes on in classrooms, which include the actions of the teacher and the students. Clearly, the teacher plays a part in the on-going dynamics of any classroom, and with the role of the teacher framed as an "instructor," the purpose of this person is to "transmit" the "knowledge" of one group of people onto another for various purposes and reasons. Experienced as such, teachers, educators and students often talk about the dynamics of the classroom as if it were an assembly line or factory. Descriptions of this kind of experience seem to suggest an unhealthy kind of organization where "relationships" are not particularly well developed, and *discipline* is the *order* of the day. Classroom teachers need to be in control. For a classroom to be "out of control" then would suggest that a teacher does not have a good "grasp" on what is going on, and that the teacher has poor class management practices. The notion of discipline takes on a particular understanding in this case.

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[196] Matt Hern, "Kids, Community, and Self-Design: An Introduction," in *Deschooling Our Lives*, ed. Matt Hern (Gabriola Island, British Columbia, Canada: New Society Publishers, 1996), 1.

Classroom subjects are also sometimes referred to as disciplines. Originally meant to refer to "the learner" (*discipulus*) and the verb "to learn" (*discere*), the notion of a discipline was reformulated to suggest "instruction" or "knowledge," and gradually has been transformed into a "maintenance of order" which is deemed necessary for providing instruction.[197] To maintain this kind of order, it is generally presumed that the manager, supervisor, teacher–quite simply, an authority figure–is to be respected or otherwise feared so that an orderly organization can be maintained or sustained. Put differently, an orderly organization, like a "mechanical" organization, is one that can easily be manipulated, held up in the hand and fixed by the gaze of its maker. The notion of a "paragon" comes to mind here.

It can more or less safely be suggested that classrooms, schools and learning organizations, in general, are not mechanical structures. Metaphorically speaking, however, some people's experiences might suggest that schools and schooling are mechanical in nature. But what is it that contributes to this sense of learning, classrooms and schools? How might it feel otherwise?

Mechanical systems tend to function in particularly well-defined ways. While the "parts" may interact with one another, they do not improvise. Cog A might turn cog B, however, the action is predictable and not open to possibilities other than the prescribed action as determined by cog A interacting with cog B. Put differently, the interaction of cogs A and B does not change anything about their interaction nor the cogs themselves. In some sense there is no relation present and they are isolated. Simplistically put, such might be the case with students, for example, who sit quietly in rows of chairs in a classroom–if students were cogs. Of course, by simply putting students into pods, as is a frequent practice of some teachers, does not necessarily increase the kinds of interactions that might give rise to the learning of particular ideas. The interactions and novel possibilities might be better suited to "ideas bumping up against one another" as opposed to merely providing the opportunity for just any kind of conversation.[198]

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[197] John Ayto, ***Bloomsbury Dictionary of Word Origins*** (London: Bloomsbury, 1991), 174.

Interactions that affect some kind of change are essential to learning organizations which must have some capacity to adapt to or keep pace with an already and always changing world. To be certain, students in a classroom where interactions are limited are not simply inert beings: these are not automata, the kind seen on a computer screen. For instance, on-going interactions in one's mind are always present, giving rise to the endless, silent (to others) conversations. Even if most or all of the communication were from the teacher, no classroom is void of interaction. There is, however, a lack of diversity in the interactions, and these can only happen through conversation and interaction amongst students and teacher. Moreover, a certain amount of redundancy is bound to be present which would create a larger emergent collective of ideas within the classroom–the learning organization. As reflected in other forms of healthy organizations, diversity, local interactions, and redundancy, therefore, would be necessary conditions for a classroom to be healthy, that is, something which students would not experience as if they were a machine of disconnected cogs. When any of these aspects are dampened in physiological systems, for example, death is usually not that far away. Certainly, my days back in high school seemed a little dull sometimes, if not deadly.

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[198] Davis and Simmt, "Understanding Learning Systems," 156.

So what would my schooling and classroom experiences have looked like if I were involved in and felt a part of a healthy learning organization? Deep down, I imagine that they would resemble my experiences with PI.

What would have happened if as individuals and collectives, people at my school followed their own curiosity? Moreover, no person shares the exact same interest at the same age. So I imagine that I would be with a number of different people–young and old alike–talking, working together, going for walks, just "hanging out," and sometimes I would be by myself. Forced segregation by age has never quite made much sense to me. Moreover, the very notion that a person can never have time to sit and think, contemplate, or day-dream without being bothered and constantly watched over seems similarly as strange. The thought of being able to sit in a cozy chair near a large window (that I could open or shut as needed) or on a bench on a veranda or beneath a tree seems like a novel idea. To some this might seem lazy, to me this would be necessary time to just be or ponder over some problem or a time to be inspired. Of course, I would also spend considerable amounts of time "playing." To me, writing, reading, thinking and conversing with others about interesting ideas is play. It is, I think, an important part of being creative.

Creativity, in other words, would be present everywhere, in many diverse forms and activities with many individuals and various group sizes pursuing our own creative ventures. Now imagine this happening all the time. There would be no need to have bells, schedules and timetables to tell people to stop doing what they were doing and working so hard at and move to another place to do something else. Learning happens across many different time scales, seldom fitting into some uniformly structured time-table.

Some days I would feel like spending the entire day in front of a computer creating programs. But, of course, every now and then I would want to go and sing with others in the music room, or go cycling in the country, learn how to make goat's cheese, and study the history of my town. Others would do similar things, following their own interests and engaging with others as they would see fit. Clearly there would be lots of things going on all-at-once throughout the school and in different rooms. The school would be a lively and busy place, and most people would have a good sense of what was going on, and who would be doing it. In other words, as a community I would be strongly connected with so many other different people that I would be able to tap into whatever kind of resource I would need. The notion of relying upon an adult to assist or guide me or answer my question no longer needs to be the case because I already know that Mary, John, Craig and Jenny enjoy singing madrigals; Benny and Sue live on a farm and are more than happy to show me how a farm works; Sally's mom works for the town library and would love to show me through the archives; and, I can apprentice with Thomas on Fridays down at his bikeshop.

At the same time, while I know that some of "the guys" are down in the machine shop taking apart this old abandoned car, there is something much more appealing about being in the kitchen where one of my friend's mom, who is a professional chef, has come in to bake some apple pies. Being the eldest of four and having the responsibility of making dinner for my family because both of my parents work, I figure I could learn some cooking tips as well. Maybe she would be interested in hearing what I tried to make for dinner from one of my mom's cookbooks.

This is hardly chaos, and it is not anarchy. But I would suspect that it is much more complex than what most people have experienced at least as far as schooling goes. Given that in this kind of context there is far less uniformity present in terms the kinds of relations that are permitted, and what can be done at particular times, defining what a healthy curriculum could be like is seemingly just as difficult. I can only speculate what that might be like.

On Curriculum

Talking about "death" would make for an appropriate segue into a discussion about curriculum. In fact, in 1969, Joseph Schwab argued that curriculum was dying: it was dying because of an overemphasis on inappropriate theory and energies had to be diverted from the theoretical to the practical. Schwab writes:

> *The field of curriculum is moribund. It is unable, by its present methods and principles, to continue its work and contribute significantly to the advancement of education. It requires new principles...a new view...of its problems...[and] new methods appropriate to the...problems.*[199]

Curriculum theorist, William Pinar, also echoed the same sentiment:

> *It is obvious that the curriculum field is now, and has been for maybe 20 years [though this number is arguable], in a period of breakdown, or in Kuhn's term, "crisis". In fact, it has been near death for at least ten years as two prominent theoreticians have noted–Schwab in 1970 and Heubner six years later.*[200]

How far might this "crisis" or "breakdown" extend throughout the education system itself? How might one recognize such systemic morbidity?

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[199] Joseph Jackson Schwab, "The Practical: A Language for Curriculum," in *Science, Curriculum, and Liberal Education: Selected Essays*, ed. Westbury I. and N. J. Wilkof (Chicago: University of Chicago Press, 1978), 287.

[200] William F. Pinar, "Notes on the Relationship between a Field and Its Journal," in *Contemporary Curriculum Discourses: Twenty Years of Jct*, ed. William F. Pinar, *Studies in the Postmodern Theory of Education* (New York: Peter Lang, 1999).

What indicators would there be to tell us that the education system is on its last legs or about to keel over?

Is "school" dead? Many critiques which emerged from within the social change of the 1960s suggested as much. The title of Everett Reimer's book, *School is Dead*, proposes so.[201] The "de-schooling" movement which also originated during this time of upheaval, stemming from the work of Ivan Illich, argued that schools had evolved in such a way that it can dampen children's learning and their own capacity to manage and direct their own learning experiences.[202] The sentiment continues today, and is sometimes put rather radically: public schooling is a "nightmare."

But do we have to live with the "nightmare"? What might a healthy curriculum look like and how might it be enacted?

William Pinar's notion of *currere* is possibly a good starting point to re-visit, where curriculum is not so much the course to be run but the running of a course. *Currere* is a verb and not a noun. In this way, it is a much more emergent notion rather than a carefully prescribed path to be traveled down throughout the academic school year with specific stops at specific times through that year. Somehow I don't see the whole project of education changing in such a profound way where children might be given the kind of freedom to live their lives out in very different ways than what most experience today. Still, there may be a very different way of envisioning curriculum from the to-be-constructed-in-advance linearly structured year that many teachers and students face every year and every day.

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[201] Everett W. Reimer, *School Is Dead: Alternatives in Education* (Garden City, NY: Doubleday, 1971).

[202] Illich, *Deschooling Society*.

One further notion that might be useful here in terms of thinking about a healthy curriculum is the notion of "all-at-once."[203] It is all the more fitting as Dennis Sumara reminds me that "currere acknowledges the existence and importance of allatonceness. It understands that the path of curriculum is 'laid down while walking' and that this path will bend, wind, and turn depending upon the particular ways relations among students, texts, teachers, and contexts develop."[204] Given that curriculum has been described as a course that is to be run rather than the running of a course, how might curriculum be structured that has this all-at-once-ness? Here, in fact, the concept of a fractal might be useful.

Given the complexities of curricula, the use of a fractal geometry could serve us well to conceptualize it in a healthy way. As with many of the canonical fractal forms, the presence of self-similarity announces a particular relation amongst its various smaller and larger parts that resonate with one another in a shared form or pattern. Imagine "pushing" at some significant node or hub within a fractal web that represents a possible curriculum (instead of some linear structure). Through a set of resonances with other similar nodes and hub of varying sizes, connections with a wide range of other concepts announce themselves. Still, I wonder how this web might emerge given the inseparability of every person's knowing-and-doing-and-being-ness. It seems to me that this kind of curricular fractal web would resonate best through the complex actions and conversations that unfold through the distributed nature of interactions of an organization of people acting locally in a diversity of ways. Put differently, not only can "we" be the web, but through the kinds of interactions necessary for a healthy learning organization the curriculum itself can also emerge, changing and adapting as needed, in the kinds of ways that announce so many of its own complexities to all through the many complex relationships that connect such a healthy living structure.

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[203] Brent Davis, *Teaching Mathematics: Toward a Sound Alternative* (New York: Garland, 1996).

[204] Dennis J. Sumara, *Private Readings in Public: Schooling the Literary Imagination, Counterpoints; Vol. 26* (New York: Peter Lang Publishing, 1996), 175.

On Space

At this point, one might be tempted to consider how space might affect the ways in which people learn and work with one another. It is tempting to try to imagine a "fractal" physical space for a classroom or school. As Alan Block writes: "The geometrical shape of the classroom determines not only what a person can do, but to a large extent, determines what he can think."[205] Long straight corridors and boxy rooms have a particular way of limiting what might be possible. In fact, the geometry is limited and limiting; it would be hard to get lost when one cannot get side-tracked in such places. There is much certainty in a straight line, inducing a Euclidean order to life. Moreover, it seems to push the lives of many and much of the school's life toward a direction of greater disconnectedness.

Most of what happens *at* school, happens *in* school. Students and teachers and gather in assigned rooms for particular periods of time. In some cases the rooms are for particular purposes–mathematics is this room, the teacher's lounge, the band and choir in another, the woodshop in another part of the school, the main office and the principal's office, and so on. And, in this manner, not only do physical bodies become isolated and limited in their actions, but so do the social bodies or bodies of knowledge: art, English, French, math, science, *etc.* In a similar fashion, schools are sometimes cut off from their surroundings or environs with no windows, or even windows that don't open, and few good places to play that lie within the boundaries of the school where no student is permitted to leave until the end of the day. Everywhere disconnected bodies, disconnected in space and time.

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[205] Alan A. Block, "The Answer Is Blowin' in the Wind: A Deconstructive Reading of the School Text," in *Contemporary Curriculum Discourses*, ed. William F. Pinar (New York: Peter Lang, 1999), 186.

Fixed structured spaces have a way of affecting the nature and number of interactions. The pattern of such settings is quite ordered, predictable and stable where spaces and bodies become quite disconnected: the relationality, in this case, becomes weakened, marking the possibility for a certain lack of liveliness and vitality. The relational, as it has been pointed out earlier, when it is dampened or lacking, plays a role in the health of many organizations, especially in physiological systems. In the context of many traditional schooling structures, then, this lack of connection can, therefore, manifest itself at another "level"–the level of ideas as when ideas can "bump into" one another affecting what is possible. Here, there appears a manifestation of connectedness being amplified, showing itself across many scales of organization. Creativity and innovation, as possibility then, are difficult to find in many organizations where interaction and diversity are dampened.

On (Educational) Leadership

There would appear to be a fair number of books and articles and individuals that have quite a bit to say about the notion and concept of "leadership." The topic is one that has been examined both in the educational literature and the complexity literature, although the thoughts and suggestions in terms of what is leader and what is leadership tend to vary. And, so I ask: What *is* a "leader"? And what is "leadership"? The topic is not so irrelevant to educational contexts.

I cannot and will not pretend that I have much to say or offer here. I have thought about it, however, and it has left me with a few emerging, tentative thoughts as I have attempted to make sense of it. Clearly, much more attention is needed for this topic, but this would be a topic requiring much more time and space than can be given here. It would appear, first of all, that there are individuals who occupy positions of "formal leadership." These are CEOs, Presidents, Prime Ministers, Managers and Administrators, *etc.* In some sense, these are also teachers, department heads, principals, school trustees, ministers of education, and so on. It might appear that, in these cases anyway, individuals in positions of leadership are "found" at the "tops" of hierarchies "wielding" a certain amount of power. It is very hard to dismiss such an understanding that some people do have.

Whether or not this might be "true" is neither here nor there for me, although the metaphorical framing is hard to ignore. What does seem problematic is the notion that one might be able to articulate all the qualities or even some qualities that leaders have or should have. It almost seems preposterous. If I only did W, X, Y and Z, I could be a leader. If it were that simple, then why are more people not identified as leaders, feel like they are leaders or occupy positions of leadership.

To talk about leaders or leadership generally is not done in the absence of "followers." One might imagine that the same kinds of questions could be asked of individuals who "follow." The notion of following seems to imply going in some particular direction, namely, the direction of a leader. The direction or purpose for going in some particular direction may not always be clear, and such uncertainty may even exist for a leader. Nevertheless, there is implicit in the leader-follower structure a relationship of some kind.

Moreover, such relations suggest a particular power dynamic differential in social interactions.[206] In the process of relating, dynamic power differentials are always at work and never static. Although it does not appear to be the case in Stacey's work, leadership as a relational quality need not be limited to two people. In process terms where the dynamics of individual and social patterning arise in the on-going interactions of bodies, one might imagine, therefore, that in the interactions with one's self, one might see a slightly different view of leadership. In some sense, it might be thought of in terms of "making up one's mind." In this manner, making decisions (even for one's self) could be construed as leadership.

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[206] Stacey, *Complexity and Group Processes.*

In light of what the complexity sciences might tell us, leadership could be construed as a distributed phenomenon or as Dick Knowles describes in *The Leadership Dance* as a "leaderful" phenomenon.[207] That is, in every relationship or process of relating, all individuals have a capacity for a "leadership gesture." The meanings of such gestures arise in the responses (that are also gestures) that pattern further interactions and sometimes even greater widespread coherence without any causal agency at work. Pointing or directing people in some particular direction is something that we all (can) do. Power relations and feelings or acts of inclusion/exclusion, however, also play a role in what direction an individual or individuals may go.

In schools or classrooms, as educational contexts, the question of the leadership gesture is a relevant feature or aspect of people's experiences. What is possible in terms of individual and collective action, as described earlier, can be understood as prescribed or proscribed actions. This can then be viewed as leadership gestures under different power differential configurations. The former (a prescriptive organization) seems fitting of an organization experienced as a machine with an individual at the top of a hierarchy; the latter (a proscriptive organization) seems fitting of an organization at play, constantly changing and evolving. Both cases suggest particular views of knowledge and knowing, and as a result particular views of surprise.

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[207] Richard N. Knowles, *The Leadership Dance: Pathways to Extraordinary Organizational Effectiveness*, 3rd ed. (Niagra Falls: Center for Self-Organizing Leadership, 2002).

Some Final Thoughts on Learning, Education and Comparative Dynamics

By some accounts, it would appear that the education system broadly speaking could be described as being "ill." Paradoxically, education continues to hold up a system that "*nurtures* the worst in humanity and simultaneously suppresses individuality and real community."[208] One might ask how the dynamics behind different aspects of education bring forth particular curricular forms. Why does there appear to be so much sickness present in education? What kinds of dynamics would need to be present for a "healthy" educational system, and what would these forms look like to us that we might recognize them?

The form of such schools might resemble a school like Windsor House, a school in North Vancouver, British Columbia. Windsor House is not like your typical school. There are no official classes or subjects, no "teachers" *per se*, no bells and so on. Windsor House is a parent-participation, democratic, academically non-coercive school with about one hundred and seventy students aged 5 to 18 and twelve staff people. It is situated in a 60's style elementary school on a lot with trees, a playground, a field and a blacktop area. It is also a publicly funded school.

Students may ask for classes and activities, and efforts are made to provide what the students have requested. Staff and parents also offer classes and activities that they enjoy doing themselves. Students are not made to go to classes, nor are they stigmatized for non-attendance. The main focus of the school is for people to run their own lives and be engaged in undertakings of their own choice. It is a vibrant community, and although things change constantly, the main ideas of respect, service, and goodwill are maintained through the hard work and generosity of the core members.

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[208] Hern, "Kids, Community, and Self-Design: An Introduction," 1.

All in all, the school functions in a very proscriptive fashion. People are always at play–serious play. Everything about the school emerges, including the rules which the entire school creates, agrees to and modifies where necessary. Every person from the five year old to the teenager to the parents and the staff participate wholly. Leadership is most certainly distributed: it is a leader-ful school.

The school is not without conflict, but functions in a way that allows people to have disagreements dealt with in respectful and serious ways. Diversity is a hugely obvious aspect of the school, and embraced in a manner that goes far beyond social difference. All in all, it is the epitome of a healthy learning organization.

A number of other schools also come to mind that resemble or share a similar philosophy. These include Sudbury Valley School in Framingham, MA, Summerhill School in the UK, and Albany Free School in Albany, NY. These are all schools (that are not "schools" in the usual sense) that work.[209] Having only read about these schools, with the exception of Windsor House which I have seen and read about, I am inclined to say that these schools are healthy organizations. That is, from a complexity-inspired frame of mind, they are fitting of the notion which I have been developing here and describe as a healthy learning organization.

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[209] See Matt Hern, ed., *Deschooling Our Lives* (Gabriola Island, BC: New Society Publishers, 1996), 108-39, for further narratives of these schools.

Recognizing schools like Windsor House requires a very different understanding of the kinds of patterns, conversations and interactions that embody the place. As such, there are not going to be any of the usually-taken-for-granted structures of most other schools and classrooms. That is, learning unfolds and emerges across a number of different scales in time and space, and not according to some arbitrary timeline and curricula of subject matter that seldom seems to make sense for so many of these students. It is not so much that school curricula are irrelevant. Rather, it is a question of timing and personal interest. Given the wealth of "resources" the school is quite prepared to deal with the needs of its community members. That is, through the distributed leadership of the community, its relationships with one another, its respect for diversity and diverse interactions across all ages, Windsor House (and schools like it) has a greater capacity for adaptation, change and evolution. It is, I think, what so many people have wished for and continue to wish for: a healthy learning organization.

Chapter 7

DÉNOUEMENT

Some "Final" Personal Reflections

One might guess that for many doctoral students, looking back upon the various knots and tangles of trying to articulate the dissertation question, theoretical frames, methods, and analyses for a dissertation, a variety of emotions and thoughts must present themselves. Oddly enough–although it does not surprise me–it is hard to recall actually forming responses that would address each of these usually-taken-for-granted aspects of a dissertation. I may have. I may not have. What has become clear to me is that the writing and significant commitment to some particular obsession–and this could only be an obsession for any one to spend so much time in such a sustained mode of inquiry–can only be known along a path laid down in walking.

The "dénouement" is taken to be the final outcome of some long complex series of events or happenings. To think that I could even recall these various twists would be ridiculous. But, to be sure, I am not particularly surprised that there have been some rather interesting turns since starting my studies. It is not even that I *should* expect twists and turns along the way, and hence the need to adapt and change. Surely, my own expectations and anticipations will undoubtedly be "out of place" with the world around–never an exact fit. This is not to say that there could or would be a particular path for me to follow. None of this could have been prescribed. It has been more proscriptive–about what works. What does surprise me, however, is *where* I have actually ended up.

It is not my intention here to go back and "unknot" or unravel the many complications of this drama. This is, after all, what the dénouement suggests: its etymology pointing to the French, *dénouer*, "to untie." I will, of course, go back and reflect upon some of the "bumps" that I ran into. (My, my…aren't there a lot metaphors here!) My intentions also are to point out how the evolution of my own thinking changed over the lifetime of my doctoral studies program. Thus, there are two inherent problematic issues at work here in the art and performance of writing a doctoral dissertation. Again, this is not particularly surprising to me.

On a couple of occasions, I know that I had read or had been told that whatever I do during my doctoral studies that it should "keep me up at night." Oddly, today, I find myself with more than a few literal and figurative "sleepless nights" as I work towards the completion of my dissertation. I look back and see parts that are still or suddenly troubling, but there are also the glimmerings of aspects and features of a research program for an emerging academic and scholarly professional–even more eclectic than I could ever have imagined. I will speak about this "path-in-the-making" shortly.

I suppose that in some sense I haven't really "strayed" too far from my original plans–something about complexity science, surprise and novelty, and an articulation of the kinds of conditions necessary for organizations where the explicit project was about learning. Not bad, really, although some may sit back and think, "Hmmm."

There are a few occasions that are of particular significance at this moment in time which are worth recalling. I had always been a person to read rather widely, and I suspect that I had been reading about complexity-related ideas and thinking with that particular frame in mind for quite some time. My friend, Dick, tells me that he learned about complexity long before he started to think and read about complex phenomena in his work place by raising bees. The bees taught him everything, he tells me.

For some reason, however, in my basement suite on a cold March night during my first year in Edmonton, I had a most profound experience. It was like one of those moments when everything just falls into place. I was reading a piece by Brenda Zimmerman: in the middle of it, I found myself reading a rather short paragraph that talked about "surprise." I paused briefly, and then my eyebrows lifted as my eyes almost popped out. This was it! The notion of "surprise" was what I had been preparing myself to focus on for quite some time. It is odd, perhaps, to phrase it that way. But, in some ways, one must be prepared to be surprised. And, I was. My attention to reading so many different kinds of works with a complexity bent led me to this place–a place of surprise. At that point, I began to consider what a "pedagogy of surprise" would entail. In other words, I started to contemplate what conditions would need to be in place for "learning" to happen, for surprising possibilities to emerge?

In the year that followed that insight, two other significant events happened: a trip to Santa Fe and a trip to Toronto. In Santa Fe, I had the wonderful opportunity to spend two weeks at the Santa Fe Institute, the world renowned research center for complexity studies. While there, I worked with a number of other educators on the modeling of complex system using StarLogo as the operating platform. The end result of a model simulating the rising and falling of tides and the emergence of sandbars proved to be quite compelling and an even stronger impetus for me to pay attention to those things that others were calling "complex systems."

A few months later, a quickly planned trip took me to Toronto. I almost didn't go, but I did bite the bullet, whipped out my credit card, and bought a plane ticket. The draw for me was an opportunity to meet with Jane Jacobs. I had just read her book *Life and Death of Great American Cities*–a book with a strong complexity orientation written almost 4 decades earlier. I knew she was getting on in age and that I would regret not taking the opportunity to see her. It was at this conference that I first learned about Plexus Institute. I knew nothing about this organization, and if I had not gone....

The long and the short of it is that I was offered an opportunity to work for this non-profit health organization (Plexus Institute) in the United States that was explicitly using complexity science principles in its thinking and work. Thus began a long love affair with complexity-related ideas in the context of health, healthcare and healthy organizations. As such, the strong presence of health-related notions throughout this dissertation should not be surprising at all. Not only were healthcare professionals addressing issues about physiological health, but others like organizational development specialists were tending to the dynamics of social interactions that could be discussed in a similar analogous fashion to physiological systems.

And, hence, a dissertation structure finally emerged: one that made sense, could be done, and continues to keep me excited.

I could never have imagined that the completion of a dissertation would be the end of a journey with nothing else to follow as if I would come up with an answer to a problem and that would be all. In fact, it makes me uncomfortable putting this work "out there" knowing–or rather believing–that inevitably there will be parts of this dissertation that sound incredulous or troubling. Indeed, even for myself right now, there are bits that I no longer agree with or that I would qualify rather strongly. Constantly questioning and on-going conversations will do that in the midst of putting a piece of writing together like this.

Case in point: a conference I attended in Washington, DC, with Everett Rogers and Ralph Stacey on the diffusion of innovations and complex responsive processes. I am near the end of this dissertation, and Stacey completely and utterly has challenged a great deal of what is wrong about applying complexity ideas too quickly to social interactions. Interestingly, there is not only something interesting and compelling about Stacey's ideas, but there appears to be a certain resonance with his notion of complex responsive processes and my emerging notion of comparative dynamics.

In fact, I feel that I have been struggling to figure out what has seemed so problematic about certain complexity science ideas and the realm of social interactions. Like Stacey, I have to come to feel that certain conceptualizations of complex phenomena are troubling, especially for those concepts involving spatial implications. In particular, the notions of "adaptive" and "systems" remain somewhat senseless in the context of human interaction, the context of conversation. Understanding and learning arise in the constant interplay of response-and-gesture that prompts only further responses and gestures. Our interactions, therefore, remain an important aspect for complex social phenomena that arise in human conversation, thinking and learning.

Human beings, as a part of biological evolution, can only survive in relation to others and must continue to evolve in those interactions through social processes of learning.[210] Put differently, "humans are fundamentally directed toward others."[211] And, not just Others, but our Selves as well as the processes of becoming and being are inherently social, giving rise simultaneously to the individual and the collective. Interactions, therefore, give rise to both mind and society, with mind shaping society and society shaping mind. Distinct, but inseparable, mind and society are the same process of human relating.

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[210] Stacey, *Complexity and Group Processes*, 22.

As a complexity scholar and group psychotherapist, Ralph Stacey offers a view of social interactions that simultaneously questions the usefulness of recent complexity science ideas and asks that we pay attention to human interactions and the patterns that arise in the "living present." He refers to this framework as "complex responsive processes."

In his most recent book, *Complexity and Group Processes*, Stacey explores an alternative way to understand human interaction.[212] In particular, as he writes, he is concerned with three questions:

- "Who am I and how have I come to be who I am?"
- "Who are we and how have we come to be who we are?"
- "How are we all changing, evolving and learning?"[213]

These questions are fundamental to understanding social relations. Stacey's notion of "complex responsive processes" offers a radically different way of thinking about how the identities of individuals and collectives emerge, how they are interrelated and how they change. His concerns arise from a need to explain what is going on when human beings are engaged in interactions. Whereas many other complexity frames offer prescriptive ways for directing or creating the conditions for certain possibilities, Stacey questions the possibility of doing such things. And, he is giving me great cause to wonder and question as well.

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[211] Ibid., 21.

[212] Ibid.

[213] Ibid., i.

Stacey's work raises some questions about a perennial worry concerning the import that a theory has for practice. This is an often discussed and debated topic where it is assumed that theory and practice are two different aspects– one involving thinking and the other action. The split, as with many other dichotomies, is often perceived as problematic. But theory and practice are inseparable. As one thinks differently, one acts differently and vice versa.

Human actions have no inside nor outside: there are no boundaries. And in this way, the human mind gives form to and is formed by social interactions. This may not seem particularly radical: some post-modernists frequently try to "push" the mind "out of the body." What is different about complex responsive processes is a need to posit a notion of wholeness, and hence parts. The inherent spatiality of other complexity-related theories is not present in Stacey's theory of social interactions. Thus, there is no system, no "internal world" (and by extension, nothing "outside"). His is a theory of temporal, dynamic processes involving gestures and responses. As such, human interactions create nothing above nor below. That is, the notions of bodies, hierarchies and nestedness become troubling. A human interaction produces only "further interactions and is its own reflexive, self-referential cause."[214]

Stacey's work evolved from the idea that certain metaphors were becoming problematic for talking about social phenomena. Human beings participate with others in interaction, not as parts in a system outside their own interactions. This, of course, renders Stacey's approach incompatible with other complexity-related perspectives. But this is not to say that one should take Stacey's approach and combine it with another since combining inconsistent theories obliterates difference and eliminates paradoxes and ultimately the evolution of novel possibilities. Synthesizing two inconsistent views does not seem acceptable to him. Like Stacey, I'm finding it troubling drawing upon certain complexity frames to describe social phenomena.

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[214] *Ibid., 5.*

Nevertheless, the complexity sciences have a great deal of appeal, analogically speaking, for Stacey's processes of relating. The problem, however, is not so much that human beings use analogies and metaphors to describe and explain various phenomena, but rather that we forget we are doing so in the first place. On the other hand, certain complexity notions seem to be quite appropriate in a complexity framing of social phenomena. Emergence and interaction, for example, can be extended to Stacey's approach. As he suggests:

> *A key insight from the complexity sciences is that interaction between entities has the intrinsic capacity to produce emergent coherence in the absence of any blueprint or program. In other words, local interaction between entities can pattern itself into local and widespread coherence without any causal agency above or below it.*[215]

The notion of non-linearity in interactions, therefore, as well as emergent novel forms, can also be brought into Stacey's approach to understanding human interactions.

Certainly, the complexity sciences have called for a re-evaluation of how we might understand and explain social interactions. We should not think, however, that this shift will improve our "social organizations." It would suggest that we might be able to create the actual conditions for a particular outcome or arrangement. One might be suspicious if someone came along selling a method to create the right conditions for a particular outcome to appear. Should one be suspicious of curriculum designers and developers, for instance? What is important to remember about Stacey's work in this context is that it is not a prescription for action, but a means for thinking about human interactions and working with it rather than trying to change it.

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[215] *Ibid., 14.*

If anything, I have come to think just a little bit differently about myself and the world around me since I first started my doctoral program. To be certain, however, complexity science in its various historical manifestations has always played a part in my thinking and conversations with a variety of individuals. And, Ralph Stacey's thinking and work marks one of the latest frames for thinking about some of the complexities of human life and experience.

I also find myself coming back to some early thinking and reading about schools, communities and learning that I did back in the mid-90s. Ivan Illich, Matt Hern, John Holt, John Taylor Gatto: individuals associated with schools like Windsor House in Vancouver, Sudbury Valley School in Framingham, MA, and Summerhill in the UK, home-schooling networks all over the world, all of which are alternative schooling settings to more traditional compulsory educational models. Somehow, back in the mid-90s I felt that these schools were better. They are non-coercive, democratically run places. They are communities where parents participate in all aspects of school life. Windsor House is even publicly funded.

I still had not quite figured out what made these kinds of schools worked. But now that I have learned a fair amount about complex phenomena–complexity science, if you will–I have come to understand why these schools seem to work in the ways that they do. These are, in my mind anyway, the epitome of healthy learning organizations where communities of people of such tremendous diversity and interactions bring forth great advances into creativity and novelty. All of this has happened because people felt the need to do what Matt Hern described as "deschooling" their lives. Mark Twain, I believe, once suggested that people should not let schools get in the way of their education. There is, it would appear to me, a few things about education, schools and classroom dynamics that seem to get in the way of healthy relations and dynamics, but much less so at schools like Windsor House.

As I work towards the completion of the work, it does seem to me that schools like Windsor House need further attention. I do see myself going "down that path" as far as future research goes. My impression thus far seems to suggest that it is a wonderful example of a complex social system. It also strikes me as an example of a healthy learning organization. Given the various time scales over which learning happens, trying to do research on and in such places requires something more than just dropping in occasionally over a short period of time. It will most assuredly require a long-term commitment and on-going engagement. As such, the complexity of this community requires a certain complicity from any researcher. As a result, this has some implications for conducting research and will require some careful thought for thinking about a research method which addresses the emergent. Perhaps complexity will also help with that. This work marks the beginning of a number of years of further research and thought into schools like Windsor House that seem to be a wonderful example of what a health learning organization could look like as a school in the public schooling system.

This work, which has unfolded over several years, has shown me how "messy" this kind of work can be and how hard learning is. It strikes as definitely being the case especially when one thinks so deeply about something in an extensive engagement. This might seem obvious, however, I have found that what I have put down on to paper in this dissertation has helped me to understand my own experiences of doing doctoral work and learning about something that remains very important and compelling to me. While it may be obvious and true that the world and its many facets, features and aspects are complex, I know have at hand an emerging collection of tools and ideas to help me understand something about the complex nature of the world, especially in relation to classrooms, schools and settings of learning.

For me, I take away as the big ideas the notions of health, comparative dynamics and learning. The three "big ideas" have been the big hooks upon which I have placed the various threads and fabric of this dissertation. Moreover, they strike me as ideas that matter a great deal to me, and, as well, they seem quite compelling. Indeed, they also seem to matter to others I have met over the past number years, and the ideas are equally as compelling to many other individuals with whom I developed an on-going relation.

Of course, this does not mark an end, *per se*. In fact, it is but another stepping stone to another "part" of my life as I enter academia, not as a student, but as a professor in a faculty of education. From here, many new and important connections have been made as a result of doing this work and will serve as important steps to future work. In particular, I can now move from the series of thought experiments which I have offered here in this work to the "field" where I will be able examine further how my work might be shared with other teachers, principals, and even more generally people who will have an interest in human affairs in other kinds of social organizations.

More specifically, this work opens up the possibility of thinking about a philosophy of complexity, issues pertaining to teacher burn-out, the heterogeneous classroom (especially the mathematics classroom), as well as, the possibility for thinking about democratic schools as models of healthy organizations. The possibilities, I think, go far beyond these projects of interest, but they do point to the promises that comparative dynamics may hold for thinking about the relations that exist between health, comparative dynamics and learning.

GLOSSARY

The words shown here are marked in boldface font as key words throughout this work as they appear for the first time.

Adaptation - as its etymology suggests, adaptation is about a "fitting to" something else. Both an organism and an environment, as operationally independent systems, undergo mutually transformative interactions, through their mutually structured coupling. Metaphorically speaking, adaptation is more toward a "dance" where the partners attempt not to step on each other's feet.

Artificial neural networks - a branch of computer science that aims to study the cognitive structures within the confines of a computer simulation. As a connectionist theory, artificial neural networks model globally emergent patterns arising from the interactions of individual structures analogous to neurons "connected" together in a network. As a simplified model of neural assemblies in the human brain, the large collection of connected nodes, which represent neurons, change over time with "experience." This approach is seen as an alternative to representing symbolic knowledge, and has proven useful in modeling certain conceptual cognitive capacities for rapid recognition, associative memory recall, and the generalizations of categories.

Bifurcation point - structurally speaking, this is the point at which a fork emerges, as with some dendritic structure like a tree or the bronchioles of one's lungs. In chaos theory, a bifurcation point marks a point for which a slight change in the parametric value shifts the number and/or quality (in terms of stability) of fixed points into a different set of oscillatory values.

Catastrophe theory - a theory framed by the evolution of occasional, sudden and discontinuous changes or "jumps" between stable attractor sets of a mechanical or living system.

Cellular automata - are a general class of dynamical systems models governed by the greater influence of nearby cells distributed in 2- or 3-dimensional space. Local rules which define the limits of interactions within the neighbourhood of a given cell are generally assumed to be the same across the entire space and give rise to complex global emergent patterns.

Chaos theory - involves the study of non-linear dynamical systems where slight differences in initial conditions can lead to wildly different emergent patterns or trajectories as determined by the governing deterministic equations of the system. Moreover, the act of forecasting the future actions of chaotic systems when minute changes in initial conditions are made becomes impossible to carry out. Such systems are sometimes referred to as "deterministic chaos" where the state of a system is determined by the system's previous state. (*Cf.*, **Deterministic chaos**)

Comparative dynamics - is a systemic comparison of the fundamental relations of a system where the focus is on the dynamics of the system and on the similarities and differences of dynamical patterns that arise from within the given system or between different systems. In the case of a given set of relations, while they may present a wide range of patterns or behaviours , the emergent patterns give rise to both single-scale or scale invariant patterns, albeit not at the same time. Descriptively and metaphorically put, comparative dynamics is attentive to the mechanical-like and not-so-mechanical nature of a living system.

Complex adaptive systems - similar to "complex systems," aspects of the system (*e.g.*, the parts of a system) also show evidence for adaptation.

Complex systems - consists of a collection of interacting parts or agents that give rise to (with or without intention) larger more complex, emergent forms. Without the qualifier of "adaptation," this allows not only for consideration of phenomena like insect societies but also agent-based models of *in silico* phenomena (*e.g.*, a StarLogo model of termites foraging for wood).

Complex responsive processes - a term which comes from complexity and management scholar, Ralph Stacey. Complex responsive processes (CRP) challenge the usual information processing view of "knowledge production" reflected in "systems thinking." CRP draws upon complexity science as an analogy for human action in qualitative processes of power relating, paying attention to both the emotional and intellectual, the creative and destructive, and the enabling and constraining. This theoretical frame expressly sidesteps a number of troubling notions of wholes as an explanatory device as well as systems, effectively abandoning the dichotomous notions of inside and outside.

Complexity - sometimes referred to as complexity science or even the complexity sciences, complexity is the study of systems that suggest a certain capacity for novel, emergent patterns. The expression occasionally stands as an umbrella term for other system paradigms like the new sciences, chaos theory, systems theory and neural networks. "Complex systems," however, is more generally associated with systems with self-organizing dynamics brought forth in the local interactions of agents. This term is sometimes conflated with the notion of "complex adaptive systems," although complex systems need not possess the quality of adaptation: such systems are generally represented as computer simulations.

Cybernetics - historically has been concerned with the communication and control of information throughout a given system, whether mechanical or living. Set roughly in two stages, cybernetics started with a focus on technological problems, involving issues pertaining to causal interactions and feedback in the early 1950s and later in the 1970s shifted to include a focus on systems that involved an observer. The former, commonly referred to as first-order cybernetic systems, proposed that systems could be created with the feature of self-correction built in (as with a thermometer). As its Greek roots suggest, *kybernetes* is about steering or staying the course. When a "cybernetics of observing systems" (rather than "observed systems") emerged a couple decades later, human complicity in relation to the "observed system" announced a new focus on what became known as second-order cybernetic systems.

Determinism - a notion that suggests that there is no possibility for accidents or novelty. The future is completely known as determined by some higher power or deity, framed by the views of mystical or religious traditions, or assumed by certain historically-situated views of science. From a scientific point of view, the notion of determinism is also used to suggest the nature of a system to determine its own direction through a closed set of operations.

Deterministic chaos - like other theoretical frames for dynamical systems, this is a concept which points to how possible states of a system can arise given a set of rules that determine a present state from a past state. What makes this theoretical frame different from others is that the rules are deterministic and that the present states of the system are uniquely determined from past states. Moreover, unlike other frames, there can be no possibility for random events although to some observer, randomness may appear.

Diffusion theory - concerned with a process whereby innovative ideas are communicated through particular channels over time amongst the constitutive members of a given social system. In the process, the participants in the system create and share information with one another in order to reach a shared or convergent understanding or practice.

Double-embodiment - a challenge to the Western view and separation of mind and body, double-embodiment is Merleau-Ponty's suggestion that the body is simultaneously understood as a physical-biological structure and an experiential-phenomenological one. Neither opposed nor separable, the physical-phenomenological body stands all-at-once in relation to the world and it's self, that is, giving shape to and being shaped by the world.

Edge of chaos - a notion that points to a "space" between organized and disorganized phenomenon. Oftentimes, considered to be the conditions under which adaptive, novel, creative possibilities can emerge.

Emergence - points to the appearance of novel identities that are generally not found at the "level" of the parts of a system, but rather at the level of collective action of the interacting parts of a system: that is, the behaviour appears at a different scale from the parts. Moreover, sometimes the "parts" of the system are complex entities themselves, although this need not be true. (*Cf.*, **Complexity**)

Enactivism - points to the evolution of one's inseparable sensorimotor abilities, perception and cognitive structures. That is, this cognitive perspective as articulated by cognitive biologist, Francisco Varela, points to the notion of a non-essential knower, an individual whose identity, knowledge and ways of knowing are enacted in the moment-to-moment coping mechanisms and possibilities arising with his/her experiences. Moreover, perception is "perceptually guided action" where ones' perceptions are not of a pre-given world, but rather are shaped through ones' recurrent and continuously elaborated sensorimotor actions: cognitive structures emerge through one's doubly-embodied nature, through one's biology and experience, as engaged with the world.

Evolution - a process of transformation whereby forms change over time, increasing in diversity and complexity. Although the word suggests an unfolding, the notion of evolution as articulated by Darwin challenged the belief that the universe was already enfolded within itself, pre-given and directed from lower, simpler forms toward higher more complex ones.

Fractal - or fractal geometry, is a branch of mathematics dedicated to the study of highly irregular shapes that display a measure of detail across all scales of the figure. Unlike a single-scale entity that "falls out of sight" at some magnification, fractal structures generally demonstrate a certain degree of self-similarity across all of its scales. Only mathematical fractals can be truly self-similar, whereas, images in nature like trees and estuaries which resemble fractal forms show a measure of scale invariance.

Genetic algorithms - a process of simulated evolution within a computer model where the biological structures of a population, whose members can mate, cross over and mutate, are mapped onto computational programs and data structures that suggest particular levels of "fitness."

Information theory - an important part of the cybernetic movement that was concerned primarily with the problem of how messages were coded and transmitted through noisy channels. This idea originated with Norbert Weiner and Claude Shannon with the latter developing this idea in the context of the efficiency of signal processing for the telephone and telegraph.

Linearity - a mathematical notion that the dependent and independent variables of a system are directly proportional. Post-modern understandings of linearity also tend to challenge the notion of pre-scribed order suggested by an implicit arrangement or natural unfolding of some phenomena.

Metaphor - often presented as a literary device for describing one thing in terms of another, a metaphor is an embodied understanding through which human beings articulate the attributes one kind of experience onto another through experientially grounded mappings.

Modernist - the quality of an epistemological orientation toward the world and how it is known that suggests that knowing the world as it exists "out there" can be ascertained through careful reason and empirical study. Modernist interpretations of the world assume that progress is linear.

Network theory - is concerned with the relationships between and among the individuals or parts of a network or system and its patterns of interaction. It is mathematical in its nature and crosses disciplinary boundaries: as such, the interconnections of parts are abstractions seen as patterns of nodes and lines as with a graph in the mathematical discipline of graph theory.

Neurophenomenology - a term created by Chilean biologist, Francisco Varela, to describe the marriage of neuroscientific and phenomenological inquiry. It is the study of conscious (lived) experience and corresponding neuronal patterns and dynamics.

Non-linear dynamics - the characterization of relationships with the property that emergent patterns or behaviours of a system or phenomenon cannot be directly known in relation to the underlying parts or mechanisms of that system.

Paradigmatic complexity - this term is used here to point out that the world is already complexity. The apparent appearance of "complexity" in the current literature and discussions of world phenomena is the mark of a growing, emergent paradigm or way of seeing and looking at the world.

Phenomenology - a discourse oriented around the notion of "lived experience" that directly explores the pre-reflective dimensions of human experience. This focus on lived-experience carries a particular power that aims to transcend the limitations of conceptualizations and codifications of modernist explanations. As a form of qualitative research, the epistemological basis for phenomenological inquiry is human experience in its raw, pre-reflective conscious form.

Post-modernism - a collection of diverse discourses that share the feature of a rejection of modernist notions like essentialism, reason and logic.

Power law - a number used to describe the distribution of a particular pattern across many scales. Put differently, the power law is a descriptor of an invariant pattern where the ratio of the number of clustered patterns of two different cluster sizes is independent of cluster size.

Property of independence - this property is a corollary to the property of proportionality. That is, each constant of proportionality is independent of one another.

Property of proportionality - a property of a system or process where, if the system is linear, the direct output of some operation is directly proportional to the input. That is, the relationship between input (x) and output (y) are expressed algebraically as $y = \alpha x + \beta$ where α is the constant of proportionality. In the special case of $\beta=0$, there is an absence of output in the system. More generally, if several factors are implicated in some system or process, then it is said to be linear if the end result is proportional to each factor.

Recursion - suggesting a "re-writing," recursion takes some element (e.g., a number, computed value or object) and applies a rule or process to the element to create a subsequent element in an on-going process.

Reductionism - a view of the world that holds that the world and claims to the truth can be reduced to a set of fundamental principles, central laws, simple assumptions and necessary causes, where knowing the lowest-level details of how things might work can reveal how higher-level phenomenon arise.

Redundancy - a superfluous abundance of interactions or parts in a system. (*Cf.*, **Variability**)

Scale invariance - an aspect of certain geometrical objects where detailed features can be observed across various degrees of magnification. Unlike traditional Euclidean geometrical objects, which have single scale properties, scale invariant structures display a given property across many scales.

Self-organization - refers to the spontaneous quality of a system for pattern formation without direction or orchestration from some authority or leader. Complex systems are often described as being self-organizing where the local interactions of agents in the system co-specify one another. The notion of a "self" is sometimes questioned, but generally implies the formation of some pattern without the influence of some external force.

Self-organized criticality - a characteristic of certain systems that do not display one typical event size. Without any significant external "tuning" or influence, the system self-organizes through a given set of dynamical interactions that produce patterns at all scales. The dynamical explanation for such phenomena points to spatial and temporal patterns which, simplistically put, reflect certain statistical properties described mathematically as power laws where the behaviour of non-average phenomenon fit a linear relationship on a double-log scale graph.

Sensitivity to initial conditions - a frequently invoked notion to describe how a different set of outcomes in a chaotic system might arise by changing, even ever so slightly, the initial state of the system. Changing the initial conditions most certainly changes the way the system unfolds over time from some starting point, but the larger enfolded patterns remains the same. A sensitivity to changes in the parametric control values of a chaotic system, however, creates the possibility for different qualitative changes to emerge in the systems itself.

Self-similarity - a quality of certain mathematical objects where a particular property or set of relations can be found at all scales of the object and ultimately at the level of the whole object itself.

System - an entity generally described as if it were a whole. Sometimes they are constructed from smaller subsystems and embedded in an environment.

Systems thinking - a scientific framework for thinking about features of living systems. Where cybernetic systems tend to abstract relations through the amalgamation of a system's parts, systems thinking tends to the physical form and arrangement of a system and the overall evolution of the system itself.

Theory - following the ancient Greeks, the notion of theory in this work is taken to mean a "way of seeing." Although not merely a way of seeing, as in a description of some phenomenon, it remains inseparable from one's actions as well. For this work, therefore, theory is practice and vice-versa.

Variability - the quality of difference within or across temporal and spatial phenomenon. In social systems, this is often described in terms of "diversity."

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